CFTRI-MYSORE
124
Vegetable crops

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124 — ⑲ peas ⑳ vine crops
㉑ solanaceous fruits
1. vegetable crops ② soils
3. vegetables ④ fertilizers
5. seeds ⑥. plant growing
7. cultivation ⑧ irrigation
⑨ vegetable marketing ⑩ perennial crops
11. potherbs ⑫ salad crops ⑬ cole crops
14. root crops ⑮ bulb crops.
⑯ potato. ⑰ sweet potato ⑱ beans

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56.	27/5/61	29/4/61
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176	29/9/62	5/10/62.

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VEGETABLE CROPS

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VEGETABLE CROPS

BY

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CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, * MYSORE. *
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Third Edition
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Vegetable crops.

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PREFACE TO THE THIRD EDITION

In the preparation of this edition the aim has been to bring the discussion on all topics up to date by the incorporation of results of investigations that have been made since the publication of the second edition. The great advances made during recent years in various fields have made it necessary to revise rather completely the discussions on many topics. This is true of discussions on fertilizer practices, soil reaction, the use of minor or trace elements to control malnutrition troubles, the control of diseases and insects and the packaging, handling, and storage of vegetables. A few topics not included in previous editions are discussed in this edition, and eleven new illustrations have been added.

Extensive use has been made of material presented in the publications of the various state experiment stations, in the United States Department of Agriculture publications, and in technical journals. Credit is given for the material used, and the citations are added to Literature Cited.

The author is indebted to a large number of teachers and research workers for suggestions and criticisms and for many of the illustrations. He wishes to express his appreciation to all of these, and especially to Drs. Paul Work, E. V. Hardenburg, J. E. Knott, G. J. Raleigh, Ora Smith, Hans Platenius, A. G. Newhall, and A. E. Griffiths for valuable suggestions and other assistance; to Miss Helen George for typing the manuscript; and to Mrs. H. C. Thompson for assistance in reading the proof.

H. C. Thompson.

Ithaca, N. Y.,
July, 1939.

PREFACE TO THE SECOND EDITION

The main purpose of this book is that of acquainting the student with the application of those scientific facts and principles that are involved in the successful production of vegetables and the successful handling of the products. Attempt has been made to bring to bear the results of experimental and research work to the solution of problems in production and handling. It is not deemed necessary or desirable to present any large part of the experimental data available. The author has reviewed a large part of the available data and his conclusions are based largely on them. In most cases the author has given his own interpretation and application of the data rather than the interpretation of the investigator.

The author believes that college and university teaching should be based mainly on principles rather than on detailed directions for performing various operations. The emphasis should be on the science rather than on the art of vegetable growing and handling. Proficiency in the art can be acquired only by practice and it is impracticable for the college to provide sufficient practice in all phases of the work to make the student proficient. It is clearly recognized that some practice is necessary to a thorough understanding of the principles involved. The so-called practical exercises, or laboratory work, should be so planned and conducted as to bring out the principles taught, rather than merely to teach the student how to perform a given piece of work.

In the preparation of this book extensive use has been made of the material presented in publications of the various state experiment stations, the United States Department of Agriculture, and in technical journals. Credit is given for the material used.

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H. C. THOMPSON.

ITHACA, N. Y.,
December, 1930.

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VEGETABLE CROPS

CHAPTER I

VEGETABLES AND VEGETABLE GROWING

Vegetable growing or vegetable gardening is one of the major divisions of the science and art of horticulture. From the point of view of the value of the products, vegetable growing, including the production of potatoes, is the most important branch of horticulture. The term "gardening" no longer defines commercial vegetable growing since a large part of the production of many crops is conducted on a large scale as a specialized type of farming rather than as gardening.

Importance of Vegetables.—Vegetable growing is an important branch of agriculture and has increased more in recent years than any other important type of crop production. In 1936 the estimated acreage of 21 of the leading truck crops (exclusive of potatoes and sweet potatoes) was 3,011,930 acres as compared with 2,485,800 acres for the 5-year average 1928–1932. The greatest increase has been in the green vegetables such as lettuce, celery, spinach, beans, peas, asparagus, and in a few others, such as carrots, muskmelons, and cucumbers. The production of such standard crops as potatoes, sweet potatoes, cabbage, and onions has increased very little over a period of 10 years. The acreage of these standard crops fluctuates greatly from year to year, but the trend upward has been less than it has been with the others.

According to estimates of the U. S. Department of Agriculture[1] the gross income from farm production including agricultural conservation payments for 1936 was $9,530,000,000, of which the value of vegetables was $880,000,000 as shown in Table I. A glance at this table will show that the only group of crops that exceeded vegetables in value was cotton and cottonseed. It should be borne in mind that these figures do not represent the total value of vegetables as they do not take into consideration the millions of home gardens in villages, towns, and cities. The value of farm home gardens is included, however.

Important Regions of Production.—While vegetables are grown for sale in every state a relatively few states produce a large part of the total for the United States. Thus seven of the leading states in potato production produced over half of the total crop in 1936. These states are Maine, New York, Pennsylvania, Michigan, Wisconsin, Idaho, and Colorado. Likewise, eight states, California, Florida, New York, New Jersey, Texas, Maryland, Michigan, and Indiana accounted for slightly over one-half of the total value of 21 of the most important vegetable crops (exclusive of potatoes and sweet potatoes) produced for sale in the United States in 1936. The acreage and value of these 21 crops grown for market and for canning and manufacture, as well as the total acreage and total value by divisions and by states for the 29 most important states, are given in Table II. It should be borne in mind that these figures are for one year only and that the growing season of 1936 might have been abnormal in some states. While these figures give a good idea of the important vegetable-producing states they are not complete. For example, they show no production for market in Maine, but vegetables are grown on a small scale for market in that state.

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[1] *Bur. Agr. Econ. Mimeograph*, Dec. 19, 1936.

TABLE I.—GROSS INCOME FROM FARM PRODUCTION AND GOVERNMENT BENEFIT PAYMENTS BY GROUPS OF COMMODITIES, 1936

Crops:	
Grains	$ 825,000,000
Fruits and nuts	490,000,000
Vegetables (including potatoes, sweet potatoes, and farm gardens)	880,000,000
Sugar crops	85,000,000
Cotton and cottonseed	915,000,000
Tobacco	250,000,000
Other crops	425,000,000
Total crops	$3,870,000,000
Livestock and livestock products:	
Meat animals and wool	$2,400,000,000
Poultry and eggs	890,000,000
Dairy products	1,850,000,000
Other products	40,000,000
Total livestock	$5,180,000,000
Total crops and livestock	$9,530,000,000*

* Includes $480,000,000 in benefit payments.

Vegetable growing for local markets is an important industry in the vicinity of nearly all of the large cities of the United States and around the small cities in many sections of the country. Market gardening is highly developed in the regions surrounding most of the important cities of the northern and western part of the United States and in the vicinity of some of the cities of the South.

The production of crops for canning and manufacture (for data, see Table II) is distributed over a considerable portion of the United States, but California and the northern states from Minnesota southward to

TABLE II.—ACREAGE AND VALUE OF 21 VEGETABLES GROWN FOR MARKET AND FOR CANNING AND MANUFACTURE IN THE FIVE DIVISIONS AND IN THE 29 MOST IMPORTANT STATES[1]

	For market		For canning and manufacture		Total	
	Acres	Value (000 omitted)	Acres	Value (000 omitted)	Acres	Value (000 omitted)
North Atlantic........	196,970	$ 28,676	194,480	$ 1,487	391,450	$ 40,163
North Central........	136,810	14,300	658,710	17,308	795,520	31,608
South Atlantic........	421,690	39,643	208,050	9,708	629,740	49,351
South Central.........	381,720	19,229	61,410	1,393	443,130	20,622
Western..............	523,440	91,936	228,650	16,804	752,090	108,740
United States.........	1,660,630	193,784	1,351,300	56,700	3,011,930	250,484
California............	385,680	72,602	140,650	11,434	526,330	84,036
Florida...............	148,050	24,000	5,100	143	153,150	24,143
New York............	66,320	12,339	99,710	4,018	166,030	16,357
New Jersey...........	102,200	11,692	43,250	4,107	145,450	15,799
Texas................	263,330	12,056	21,130	420	284,460	12,476
Maryland............	31,220	3,193	123,040	6,225	154,260	9,418
Michigan.............	33,170	5,396	60,670	2,217	93,840	7,613
Indiana..............	25,810	2,093	154,950	5,343	180,760	7,436
Colorado.............	42,340	5,630	11,610	681	53,950	6,311
Arizona..............	46,040	6,074	40	4	46,080	6,078
Washington..........	24,840	4,115	24,200	1,551	49,040	5,666
Pennsylvania.........	22,970	3,555	29,450	1,955	52,420	5,510
Wisconsin............	12,800	1,436	132,520	3,780	145,320	5,216
Virginia..............	37,700	2,592	34,270	1,273	71,970	3,865
Ohio.................	11,170	2,093	53,970	1,529	65,140	3,622
South Carolina........	62,250	3,358	1,600	31	63,850	3,389
Georgia..............	83,200	2,895	9,400	321	92,600	3,216
North Carolina........	50,450	2,920	4,150	232	54,600	3,152
Oregon...............	10,310	1,617	23,350	1,453	33,660	3,070
Mississippi...........	36,200	2,565	6,440	145	42,640	2,710
Minnesota...........	5,860	720	89,520	1,665	95,380	2,385
Delaware............	8,820	685	29,140	1,429	37,960	2,144
Utah................	3,770	636	20,550	1,305	24,320	1,941
Louisiana............	26,830	1,727	2,280	39	29,110	1,766
Maine...............	....	....	19,100	1,266	19,100	1,266
Massachusetts........	5,480	1,090	520	25	6,000	1,115
Iowa................	5,990	427	46,390	557	52,380	984
Idaho...............	8,030	800	3,720	138	11,300	938
Missouri.............	22,160	881	5,660	44	27,820	925

---

[1] The crops included are artichokes, asparagus, lima beans, snap beans, beets, cabbage, cantaloupes, carrots, cauliflower, celery, sweet corn, cucumbers, eggplant, kale, lettuce, onions, peas, peppers, spinach, tomatoes, and watermelons.

Missouri and eastward to Maryland and Maine produce a large percentage of the acreage of the vegetables used for these purposes. The leading states in the production of such crops in 1936 were as follows:

Snap beans: Maryland, New York, Oregon, Michigan, Wisconsin, California, Maine, and Washington.

Cabbage for kraut: New York, Wisconsin, Ohio, and Michigan.

Sweet corn: Illinois, Minnesota, Maryland, Maine, Iowa, Indiana, Ohio, and New York.

Cucumbers for pickles: Michigan (about one-fourth of the crop), California, Wisconsin, Illinois, Colorado, Indiana, Ohio, and New York.

Peas: Wisconsin, Minnesota, New York, Utah, Maryland, and Washington.

Tomatoes: Indiana, California, Maryland, New Jersey, New York, Virginia, Ohio, Pennsylvania, and Delaware.

Asparagus: California produced nearly all of the asparagus used for canning.

TYPES OF VEGETABLE GROWING

Vegetable growing may be divided into five divisions, based on the objects sought and the methods employed in producing and in disposing of the crops. These divisions are: (1) home gardening, (2) market gardening, (3) truck growing or truck gardening, (4) canning crop production, and (5) vegetable forcing. These types of vegetable growing have developed as the population has changed step by step from a rural toward an urban population and may be considered as an evolution.

Home Gardening.—In the colonial days in America the family was mainly self-supporting and the vegetables that were consumed were grown in the family garden. This is still an important part of vegetable production. According to the Bureau of the Census the value of the vegetables grown in farm home gardens in 1919 was $344,665,728. In that year 78.9 per cent of the farms in the United States had home gardens and the average value of the products produced in them was $68. Furthermore, there are millions of gardens in villages, towns, and cities, the aggregate value of whose products runs into many millions of dollars. More important than the value, as reckoned in dollars and cents, is the relation of these vegetables to the health of the people whose only available supply is from those grown at home.

It is often said that it is cheaper to buy vegetables than to produce them on the general farm. As a rule the person making such a statement is considering the price at which vegetable growers sell their produce at wholesale rather than the price the farmer has to pay in retail stores. It is the latter price that should be used in estimating the value of the homegrown produce and when the retail price is used it will be found that in most cases the vegetables can be grown more cheaply than they can be purchased. Fresh vegetables are not always available in stores in country communities and it is seldom that a farm family has an adequate supply of vegetables unless they are produced on the farm. In most types of farming, no area of the same size produces as much in value as a well-cared-for home garden.

LOCATION OF THE HOME GARDEN.—As most of the work in caring for the garden is done in spare time the location selected should be as close to the house as is practicable. Nearness to the house is also of importance in the gathering of vegetables, since this is usually done by the women of the family. In dry regions it is desirable to locate the garden where it can be irrigated easily and conveniently, and in cold, exposed sections of the country location with reference to protection from the winds is important. In most sections of the North a southern or southeastern exposure is desirable since the soils on these exposures get warm earlier in the spring.

PLAN AND ARRANGEMENT OF THE GARDEN.—The plan and arrangement of the garden should be determined by the size of the area to be used, the slope of the land, and the kind of cultivation to be given. In a small garden cultivated by hand the rows may be closer together than for horse cultivation. The farm garden should usually be planned for horse cultivation and the area should be long and narrow rather than square. The rows should run the long way of the garden and it is desirable to have turning spaces at the ends.

The size of the garden depends on the number of persons to be supplied, but it is better to have a small well-kept garden than a large one poorly cared for. By close attention to succession cropping and intercropping, ¼ acre of land may be made to supply a family of six. Where land is plentiful it is often desirable to set aside enough land to allow a part of the garden to be planted to a soil-improving crop each year, but this is not essential where plenty of manure is available.

The location of perennial crops such as asparagus, rhubarb, and small fruits should be given careful consideration. These should be placed at one side or at one end of the garden where they will not be in the way when the garden is plowed. Long-season crops or those occupying the land throughout the growing season should be planted together. Quick-maturing crops should be planted in contiguous rows so that the area may be planted to a single late crop. It is desirable to plant tall-growing crops together and locate them so they will not shade the lower growing crops.

An inexperienced person should make a plan on paper before undertaking the planting of a garden. This plan should show the location of all of the crops, the space devoted to each, the crops that are to follow the early ones, and the distance between the rows. It should be possible to calculate from the plan the quantity of seed required for each vegetable.

The principles of production of vegetables for home use are essentially the same as for production for market. In the selection of varieties for home use, edible quality should be given first consideration.

Market Gardening.—Market gardening may be defined as that branch of vegetable growing which has for its object the production of vegetables for a local market.

In the early days when the population was scattered and there were no cities and towns, each family produced its own vegetables. As towns and cities sprang up, market gardening developed to meet the needs of those members of the population who had no land. For a long time this industry was confined to the immediate vicinity of the cities, but as the population increased and the demand for vegetables grew the area was greatly enlarged. However, until comparatively recent times (since 1900) most market gardens were within 10 to 15 miles of the cities, but with the building of good roads and the development of the motor truck the market-gardening area has been greatly extended.

Prior to 1860 market gardeners supplied a large part of the vegetables consumed in cities, for truck growing was almost unknown at that time, except to a very limited extent along the railroad and steamship lines leading out 50 miles or so from a few of the larger cities. While the market-garden areas around many of the large cities are increasing in size, market gardening is not developing so rapidly as truck growing.

Owing to the increasing production of vegetables in regions especially suited to their production, market gardeners are facing keen competition. This is leading to more specialization in production and to more attention to the grade and appearance of the products. Markets are no longer local. Consumers in villages and cities are able to obtain fresh produce from all parts of the United States and during most of the year. These changes, which were made possible by the development of good transportation and good refrigeration, have removed many of the advantages the market gardener had in the early days of the industry. On the other hand, the development of good roads and of the motor truck has so extended the market-gardening area that the market gardener is no longer forced to confine his operations to the immediate environs of the market. These developments have so changed the situation that the old distinction between market gardening and truck growing no longer holds. In the main the market gardener is producing those crops for which the climate and soil are best suited.

Truck Growing.—Truck growing may be defined as the producing of special crops in relatively large quantities for distant markets. In general, truck growing is more extensive and less intensive than market gardening, but there are exceptions. Some crops grown by truck growers are produced intensively.

The early development of truck growing was along the railroad lines and water courses of the eastern seaboard, especially in New Jersey, Delaware, Maryland, and Virginia. According to the census report for

1900 the steamer *Roanoke* in 1854 carried the first shipment of 200 barrels of vegetables from Norfolk, Va., to New York. Prior to the development of refrigeration and the refrigerator car, production of perishables for market was limited to regions relatively near the market. The first experiments in the use of ice for refrigeration in transit were made in the fifties but it was not until after 1880 that the carrying of vegetables in refrigerator cars began. The first all-rail shipment of vegetables to New York City from Norfolk, Va., was in 1885, from North Carolina in 1887, and from Charleston, S. C., in 1888. Since about 1900 there has been a rapid development of vegetable growing in the various parts of the United States, especially in the South and West. The southern states and parts of California have become important in vegetable production largely because vegetables can be produced in those regions at times of the year when they cannot be produced in other regions.

Production for Canning, Manufacture, and Freezing.—The growing of vegetables for canning, manufacture, and freezing is an important industry in many sections as is indicated in Table II. The most important crops grown for these purposes are tomatoes, peas, sweet corn, asparagus, beans, and cucumbers. The acreage devoted to the growing of the crops used for canning, manufacture, and freezing in 1936 was 1,351,300 acres and the farm value of the product was $56,700,000.

The regions that have the most favorable growing conditions tend to become the leaders in the production of certain vegetables for canning and manufacture. Other factors, however, have an effect on the development of vegetable canning and manufacturing industries even where the growing conditions are not the most favorable. In some instances factories are located at certain points because of the supply of fruits available, and vegetables are canned also, even though the conditions are not very favorable for their production.

The increase in the production of fresh vegetables during the winter in the South and in California and the importations from Mexico, Puerto Rico, and Cuba are giving canners concern. The use of the quick-freezing method of preserving vegetables is having some effect on the consumption of the canned product and it is probable that quick freezing will continue to develop rapidly.

Vegetables for the canning factory generally are produced on a more extensive scale than when grown for the general market. Less intensive methods are followed with most crops than are followed with the same crops produced for market. Most of the vegetable canning crops are produced by the general farmer, in rotation with grains and other standard farm crops rather than by the vegetable grower. However, the market gardener and the truck grower, in some regions, often grow crops for canning. Since earliness is not usually very important, heavier soils are selected for canning crops than for the same crops grown for the market. The cost of production per acre and per ton is usually less for canning crops than for similar crops grown for market, because of lower land value, less hand labor, smaller quantity of fertilizer, and lower cost of handling. This last is due to the fact that the canning crops are not specially prepared, and there is either no expense or a very small expense for packages. In some cases the canners furnish packages, but even where they do not, the expense to the grower is relatively low because the packages are returned.

Quick Freezing of Vegetables.—The freezing method of preservation of vegetables began in a small way in 1928 and has grown very rapidly since that time. It is estimated (Western Packer and Canner Yearbook **30,** 1938) that approximately 70,000,000 pounds of vegetables were preserved by freezing in 1937. The pack of frozen vegetables was considerably higher in 1938 than in any previous year. Peas, Lima beans, snap beans, sweet corn, asparagus, and spinach constitute a large part of the pack of frozen vegetables, but other kinds are frozen on a small scale.

Two general methods of freezing are in use—"sharp freezing" and "quick freezing." In the first, the prepared vegetables are placed in cold-storage rooms specially constructed to maintain low temperatures. In the second, several methods are followed, including (1) floating the product to be frozen in pans of running brine, (2) freezing on flat, metal plates over flowing brine, and (3) freezing the product in a package between moving or stationary cold plates. Special freezing cabinets have been designed for quick freezing, made up in various sizes. One type is a self-contained unit, requiring no auxiliary refrigeration machinery, as a light-weight ammonia compressor is mounted beneath the freezing cabinet. This machine is particularly adapted to the freezing of vegetables and fruits since it is portable and can be moved to the producing region when needed.

Freezing preserves the food value, flavor, color, and edible quality better than any other method of preservation. Freezing results in marked changes in the product due to the formation of ice crystals in the tissues, but the change is much less in quick than in slow freezing.

Some advantages of quick freezing over slow freezing are as follows:

1. The freezing period is much shorter, so that there is less diffusion of salts and less withdrawal of water from the cells in ice formation.
2. The ice crystals are much smaller and the cells are less damaged by ice formation.
3. The product is quickly cooled below the temperature at which most bacteria, molds, and yeast grow; thus decomposition is prevented during the process.

Vegetables to be frozen should be of good quality, should be harvested when they are in prime condition, and should be prepared and frozen as quickly as possible after harvest. Many vegetables, especially peas, sweet corn, Lima beans, and asparagus deteriorate rapidly in quality after harvest, the rate of deterioration increasing as the temperature rises. Preparation of vegetables for freezing includes sorting, trimming, washing, blanching in hot water or steam, and rapid cooling in running water. The blanching fixes the color and inactivates the enzymes, thus stopping deterioration due to enzymatic action.

Results of studies made by several workers indicate that there are marked varietal differences in adaptability to quick freezing. Some varieties of snap beans, Lima beans, peas, sweet corn, and other crops are much superior to others. Some of the varieties of crops recommended by various workers are as follows: Asparagus: Mary Washington and Martha Washington. Beans, snap: Kentucky Wonder, Blue Lake, Refugee, and Stringless Greenpod. Beans, Lima: King of the Garden, Fordhook, Henderson. Broccoli: Christmas Calabrese. Sweet Corn: Golden Bantam, Golden Cross, and other yellow hybrids. Peas: Any large-seeded, bright green variety. Spinach: Any broad-leaved variety of good quality. Squash: Golden Delicious, Hubbard, Golden Hubbard, and Blue Hubbard. Since new varieties and strains come on the market from time to time, one interested in growing vegetables for freezing should consult specialists of the experiment stations in his state before deciding which varieties to grow.

Frozen foods should be kept in that condition until they reach the consumer. This requires low-temperature storage, usually from −5°F. to +5°F., depending on the kind of vegetable; transportation under a temperature of +10°F. or lower; and storage and display in the retail store in refrigerator cases at +10°F., or lower. Special refrigerator cars and trucks are used for transporting frozen foods. Standard refrigerator cars are not satisfactory.

Vegetables can be frozen at any time in the year and held in storage until wanted. It might be expected, therefore, that the vegetable-freezing industry will develop mainly in regions where the growing conditions are well adapted to the growth of the crops to be frozen. High quality, large yields, and relatively low costs per unit are likely to determine the regions of production of vegetables for freezing.

Methods of producing vegetables for freezing are similar to those used for production for canning or for market in the fresh condition.

For technical details on the processing, freezing, storage, transportation, and handling of frozen products, the reader is referred to special publications on the subject.

Vegetable Forcing.—Vegetable forcing is the growing of vegetables out of their normal season and is accomplished by means of artificial heat, or in some cases by means of protection from cold. Greenhouses are the common structures used for forcing vegetables, especially in the North, although hotbeds are used to a considerable extent in some sections for forcing lettuce, radishes, and other small vegetables. In the South cold frames are used to a considerable extent for hastening various crops. Cloth-covered frames are used for considerable areas of lettuce in North Carolina and glass-covered frames are in use in the vicinity of Norfolk, Va., for growing many vegetables, including cucumbers and celery in the spring. Cellars, caves, and specially built houses are employed in growing mushrooms and in forcing rhubarb and asparagus. These crops are forced in the dark so that glass is unnecessary.

Vegetable forcing has developed because of the demand for fresh vegetables out of season. It has grown up mainly as an adjunct to market gardening, although at the present time many greenhouse men do not produce any vegetables out of doors. The vegetable forcing industry has developed mainly in the eastern part of the country, especially the greenhouse forcing industry. Some of the important vegetable forcing centers are Boston, Mass.; Rochester, N. Y.; Erie and Philadelphia, Pa.; Ashtabula, Cleveland, and Toledo, O.; Grand Rapids, Mich.; Chicago, Ill.; Terre Haute, Ind.; and Davenport, Ia. Some vegetable forcing has developed around nearly all of the northern cities, and about many of the southern and western cities.

The enormous expansion in vegetable production in the South and in California during recent years has resulted in serious competition between greenhouse-grown vegetables and those grown in the open. The cost of producing vegetables under glass is high and greenhouse growers are not able to compete on a price basis with growers who produce the same crops out of doors. To be successful, greenhouse vegetable growers must produce the crops when the outdoor supply is limited or they must produce high-quality products that will command high enough prices to cover costs. Most of them aim to meet both of the conditions mentioned. The quantity of greenhouse vegetables that can be sold at a price to pay the cost of production and a profit is very limited, for most consumers cannot afford to pay the high prices demanded for them.

Since vegetable forcing is a very specialized industry requiring detailed treatment and discussion it is not considered further in this book.

CLIMATE AS A FACTOR IN VEGETABLE GROWING

Climate is the most important factor in determining the regions of production of vegetables. Of course, transportation facilities must be available, but since all important agricultural regions of the United States are provided with good transportation facilities the present regions of production have no monopoly on these facilities. Nearly all the important vegetable-growing regions of the South and of parts of California and the Southwest are important because the climate of those regions permits production during winter and spring when other regions cannot produce vegetables. In fact, these regions have become important in spite of transportation handicaps in the form of long hauls and high cost of transportation. While good refrigerator car service and good railroads make it possible for the Imperial Valley of California to be an important lettuce and muskmelon center, no one would produce these crops there because of these factors alone, for regions nearer the important markets have as good transportation facilities with shorter hauls and lower costs. All vegetable regions located at long distances from market are important primarily because of suitable climatic conditions for the production of the crop or crops at the time they are grown. For example, the Imperial Valley produces lettuce during the winter, when the climate is satisfactory for the crop, and muskmelons in the spring and summer when the hot, dry weather is favorable for the growth and ripening of this crop. The area around Salinas, Cal., is the most important summer lettuce-producing region of the United States primarily because of the relatively low summer temperatures. In spite of high transportation costs these regions, and a few others in the West, now control the lettuce market in the large cities of the Midwest and East. Similar illustrations can be given for nearly all of the other important vegetable crops.

Favorable climatic conditions are essential for successful production of crops for canning and manufacture since high yields and good quality are important and these cannot be obtained in regions having an unfavorable climate.

In growing for local markets the market gardener no longer grows all of the kinds of vegetables that it is possible for him to produce. He confines his efforts largely to those for which his climatic and other conditions are favorable, for he has found that he cannot compete successfully with other growers who produce under the most favorable conditions

The climatic factors that are important are temperature, rainfall, and atmospheric humidity. Of these, temperature is most important in determining the broad localization of vegetable growing. Rainfall is of great importance where irrigation is not practiced and atmospheric humidity is important with many crops. Low humidity along with high temperature make the Imperial Valley and some sections of Arizona and Colorado important in muskmelon production. In the production of many kinds of vegetable seeds, absence of rain, or relatively light rainfall, and low humidity during ripening, harvesting, and curing of the seed are very important. Parts of California and of some of the northwestern states are important in the production of some kinds of seeds largely because of these favorable climatic factors.

SOIL AS A FACTOR IN VEGETABLE GROWING

The character of the soil usually is an important factor in localizing vegetable growing within a region having suitable climate for the crop or crops to be grown. The soil, however, does not determine the broad general region of production because soils of similar characteristics are found in nearly all regions of the United States. Within a region having suitable climatic conditions the location of areas of desirable soil determines to a large extent the localization of vegetable production. For example, deposits of good muck soil determine the important areas where celery is grown in New York and Michigan and the areas of onion production in Ohio, Indiana, Michigan, and New York.

While vegetables for near-by markets are often produced on soils not well suited to their growth, the soils selected are usually the best available. In this case, nearness to market may offset the disadvantages of ill-adapted soils provided other conditions are favorable. Growers located near a good market can afford to go to considerable expense to improve the soil, since they have relatively low transportation costs and the advantage of getting the products to market in a fresh condition.

The characteristics of desirable soils for vegetable production are discussed in Chap. III.

FOOD VALUE OF VEGETABLES

Vegetables play a very important role in the human diet, supplying some of the things in which other food materials are deficient. They are important in neutralizing the acid substances produced in the course of digestion of meats, cheese, and other foods; they are of value as roughage, which promotes digestion and helps to prevent constipation; they are important sources of the mineral elements needed by the body, being especially rich in calcium and iron; they are valuable sources of vitamins; some vegetables, such as the legumes, are sources of protein, while others, such as potatoes and sweet potatoes, are important sources of energy, being rich in carbohydrates. It has been known for a long time that vegetables are of greater importance in the diet than could be accounted for on the basis of their content of protein, carbohydrates, and fats.

Vegetable Foods as Base Formers.—The mineral substances are the agencies that are chiefly concerned in the reaction of the body fluids. Some of these elements are acidic and others basic—phosphorus and sulphur forming phosphoric acid and sulphuric acid respectively, while calcium, magnesium, and potassium are the most important bases acting to neutralize these acids. The bases should be in excess of the acids in order that they may serve as alkali reserves of the blood. Table III shows the excess acid or base in the vegetables and other foods as reported by Ripperton and Russell (1926).

TABLE III.—EXCESS ACID OR BASE PER POUND OF THE FOODS LISTED, THE FIGURES DENOTING THE EXCESS OF ACID OR BASE IN TERMS OF CUBIC CENTIMETERS OF NORMAL SOLUTION REQUIRED FOR NEUTRALIZATION

Food material	Normal acid, cc.	Normal base, cc.	Food material	Normal acid, cc.	Normal base, cc.
Cabbage	....	21.8	Fish, halibut	35.1	
Cauliflower	....	24.3	Meat, beef, lean	44.2	
Lettuce	....	27.9	Cheese	24.9	
Onions	....	6.2	Milk, cow's, whole	....	8.1
Spinach	....	122.0	Eggs	45.0	
Beans, Lima, fresh	....	29.0	Bread, white	31.9	
Beans, string, fresh	....	22.7	Rice, white	42.9	
Peas, shelled, fresh	....	3.3	Apples	....	12.8
Beets	....	39.4	Oranges	....	18.4
Carrots	....	37.8	Pineapples	....	30.8
Potatoes, white	....	26.0	Raisins	....	97.0
Potatoes, sweet	....	24.1			

Vegetables as a Source of Minerals.—At least 10 mineral elements are needed for the proper growth and development of the body. Extensive investigations have shown that calcium, phosphorus, and iron, except in rare instances, are the only mineral elements that are not present in foods in quantities sufficient for the needs of the body. Vegetables are important sources of calcium and iron. The green vegetables are rich in iron, especially spinach, dandelion greens, chard, cabbage, asparagus, and green beans.

Vegetable Foods as Sources of Roughage.—A certain quantity of bulky food is necessary for good health; vegetables are the main source of "roughage." Most vegetables, particularly the leafy ones, as celery, cabbage, spinach, lettuce, and others, are characterized by high water content and relatively high percentage of cellulose or fiber. Because of their succulence and relatively large bulk the leafy vegetables and most of the root crops probably aid in the digestion of the more concentrated foods, as well as prevent or overcome constipation.

Vegetables as a Source of Vitamins.—The name "vitamin" has been given to a group of food substances other than fats, proteins, carbohydrates, and salts that occur in small quantities in natural food materials. They are essential for growth, for reproduction, and for the maintenance of health. Six vitamins are known: A, B, C, D, E, and G. According to Sherman (1933) each vitamin is specific in that no one or combination can take the place of any other one. An excellent review of the available information on vitamins has been published by Daniel and Munsell (1937). The following discussion of vitamins is based largely on this review.

Vitamin A is essential for growth, for reproduction, and for the prevention of the eye disease, xerophthalmia. Populations deprived of it have a high death rate due to infections of the lungs and intestines, according to some authorities. Vitamin A activity has been traced to the presence of three carotinoid pigments and a xanthophyll pigment. All of these are converted into vitamin A in the liver and are therefore called "precursors" of vitamin A.

Vitamin B is essential for the maintenance of a normal appetite, for milk secretion, and for the prevention of the disease beriberi.

Vitamin C is essential for the prevention of scurvy and for healthy gums. It has been identified as ascorbic acid.

Vitamin D is essential for the proper utilization of calcium and phosphorus salts in the nutrition of the bones and teeth, and for the prevention of rickets and diseases of the teeth. This vitamin is derived from the plant sterol ergosterol when this substance is exposed to ultraviolet light.

Vitamin E is essential to rats and other animals for successful reproduction; it is not known that it is essential for human beings. It is widely distributed in the natural foods of man.

Vitamin G is essential for growth of the young and for the prevention of pellagra, a deficiency disease. Some authorities restrict the name to designate the flavin (or flavins) that possesses the power to promote growth and to prevent a condition in the rat known as "nonspecific dermatitis." Some investigators consider lactoflavin, a flavin found in fairly high concentration in milk and in green leaves, as identical with vitamin G.

Table IV gives the relative distribution of vitamins A, B, C, and G in many vegetables. As used in this table, + indicates that the food contains the vitamin; ++ indicates that the vegetable is a good source; +++ indicates that the vegetable is an excellent source; − indicates that the vegetable contains no appreciable quantity of it; and * indicates that evidence of its presence is lacking or appears insufficient.

Dye, Medlock, and Crist (1927) and Crist and Dye (1929) have shown that the vitamin A content is associated with greenness in plant tissue.

Dye, Medlock, and Crist worked with lettuce and their results indicate that leaf lettuce exceeded head lettuce in the promotion of growth in rats that had ceased to gain on a diet deficient in vitamin A. The outside, green leaves of head lettuce were far superior to the inside yellow leaves in furnishing vitamin A. In their studies of green and bleached asparagus, Crist and Dye found that green asparagus whether fresh, freshly cooked, or canned, when fed daily at the rate of 0.1 gram per animal, supplied vitamin A in quantity sufficient to promote health and growth in albino rats. Fresh bleached asparagus, when fed daily at the rate of either 0.1 or 0.5 gram per animal, gave no stimulus to health and growth. The animals died as rapidly as the negative controls. Cooking in open kettle improved the nutritive quality of bleached asparagus, but did not make it comparable to the green product cooked in the same way.

TABLE IV.—RELATIVE DISTRIBUTION OF VITAMINS A, B, C, AND G IN VEGETABLES

Name of vegetable	Vitamin A	Vitamin B	Vitamin C	Vitamin G
Artichoke, Globe	++	+	*	
Asparagus	Variable	*	++	*
Beans, snap	++	++	++	++
Beets, root	+	+	+	+
Brocooli, green	++	++	+	++
Cabbage, head, raw	+	++	+++	++
Carrots	+++	++	++	++
Cauliflower, cooked	+	++	+	++
Celery stalks, bleached	− to +	++	++	*
Chard	++	+ to ++	*	*
Collards	+++	++	++	++
Corn, white	+	++	−	+
Corn, yellow	++	++	−	+
Cucumbers	− to +	+	++	*
Dandelion greens	++	++	+	++
Eggplant	+	+	+	*
Kale	+++	+	++	+++
Lettuce	+ to ++	++	++	++
Muskmelons	++	++	++	
Onions, raw	− to +	+	++	+
Peas, green	++	+ to ++	+++	+
Peppers, green	++	++	+++	*
Potatoes	+	++	++	++
Pumpkin	++	+	+	+
Spinach	+++	+	++	++
Squash, Hubbard	+++	+	*	+
Sweet potatoes	+++	++	++	++
Tomatoes, raw or canned	++	++	+++	+
Turnip greens, cooked	+++	++	+++	++
Turnips, white	− to +	+	++	+

Composition and Fuel Value of Vegetables.—While vegetables in general are not considered of great importance in furnishing proteins and carbohydrates, some of them, as the dried seeds of beans, peas, and lentils, are rich in proteins. Others, as potatoes, sweet potatoes, parsnips, carrots, turnips, and rutabagas, are important sources of carbohydrates. Based on the average yield for the 5 years 1928–1932, an

Table V.—Proximate Composition of Vegetables
(U. S. Dept. Agr. *Circ.* 146, 1931)

Kind of vegetable	Refuse, per cent	Edible portion							
		Water, per cent	Protein, per cent	Fat, per cent	Ash, per cent	Carbohydrates			Fuel value per pound, Cal.
						Fiber, per cent	Sugar, per cent	Starch, per cent	
Asparagus	25	93.0	2.2	0.2	0.67	0.7	1.34	0.4	120
Beans, Lima	60	66.5	7.5	0.8	1.71	1.5	....	....	595
Beans, snap	10	88.9	2.4	0.2	0.77	1.4	0.37	2.2	190
Beets, greens	..	90.4	2.0	0.3	1.70	1.4	0.50	....	150
Beets, root	25	87.6	1.6	0.1	1.11	0.9	....	....	205
Brussels sprouts	23	84.9	4.4	0.5	1.28	1.3	....	....	260
Cabbage	27	92.4	1.4	0.2	0.75	1.0	3.50	....	130
Carrots	37	88.2	1.2	0.3	1.02	1.1	7.50	....	205
Cauliflower	55	91.7	2.4	0.2	0.85	0.9	2.60	....	140
Celery	37	93.7	1.3	0.2	1.08	0.7	1.25	....	100
Chard (leaves)	..	91.0	2.6	0.4	1.20	0.8	0.82	0.1	150
Corn, sweet	62	73.9	3.7	1.2	0.66	0.8	4.29	14.6	490
Cowpeas, green	..	65.9	9.4	0.6	1.40	...	....	....	605
Cucumbers	30	96.1	0.7	0.1	0.44	0.5	2.60	....	65
Kale	..	86.6	3.9	0.6	1.70	1.2	1.19	0.2	225
Lettuce	31	94.8	1.2	0.2	0.91	0.6	1.60	....	85
Okra	12	89.8	1.8	0.2	0.84	1.0	....	....	175
Onion bulb	6	87.5	1.4	0.2	0.58	0.8	6.70	0.5	220
Parsnip	22	78.6	1.5	0.5	1.15	2.2	9.50	2.4	380
Peas, green	55	74.3	6.7	0.4	0.92	2.2	3.20	8.2	460
Peppers, green	16	92.4	1.2	0.2	0.50	1.4	1.70	4.2	135
Potatoes	16	77.8	2.0	0.1	0.99	0.4	0.87	14.7	385
Pumpkin	31	90.5	1.2	0.2	0.82	1.3	2.50	2.6	160
Radish	51	93.6	1.2	0.1	0.95	0.7	3.40	....	100
Rutabagas	15	89.1	1.1	0.1	0.83	1.3	6.70	....	185
Spinach	18	92.7	2.3	0.3	1.53	0.6	0.30	....	110
Squash, summer	3	95.0	0.6	0.1	0.44	0.5	1.00	0.2	85
Squash, winter	26	88.6	1.5	0.3	0.83	1.4	3.90	1.0	200
Sweet potato	14	68.5	1.8	0.7	1.07	1.0	5.35	20.2	565
Tomato	2	94.1	1.0	0.3	0.57	0.6	3.37	....	105
Turnip, root	13	90.9	1.1	0.2	0.73	1.1	4.60	....	155
Turnip, tops	16	89.5	2.9	0.4	1.76	1.2	....	....	165

acre of potatoes produces considerably more carbohydrates and more protein than an acre of winter wheat. An average acre yield of carrots produces more than twice the quantity of carbohydrates and nearly twice the quantity of proteins as an average acre yield of winter wheat. The approximate composition of many of the commonly grown vegetables is given in Table V.

CHAPTER II

CLASSIFICATION OF VEGETABLES

Before an attempt is made to give an analysis of the methods of growing vegetables it seems desirable to classify the crops. Any method of classification systematizes to some extent the preparation and presentation of the material and eliminates unnecessary repetition of some of the principles of culture. While an alphabetical arrangement of crops is the best for reference, it does not contribute to an understanding of relationship or similarity of cultural requirements. There are four general methods of classification as follows: (1) a botanical classification, (2) a classification based on hardiness, (3) a classification based on parts used, (4) a classification based on essential methods of culture. A fifth method combining parts of the four mentioned may be used to advantage in grouping crops for discussion.

Botanical Classification.—A classification based entirely on relationship is the most exact system, but in many cases this is of little value in giving principles of culture since crops within a family may vary widely in their requirements. Potatoes and eggplants belong to the same family but their requirements are very different. However, other crops in this family, as tomatoes, eggplants, and peppers, have similar requirements. Most of the vegetables belonging to the family Cucurbitaceae have similar cultural requirements as well as the same disease and insect pests. This is also true of plants in many other families.

The botanical system of classification is of value in showing relationship and is given to show the families represented, as well as the important vegetable crops belonging to each.

Plants are divided into four great groups, or as Bailey calls them, "subcommunities." These are as follows:

I. Thyllophyta	The thallophytes.
II. Bryophyta	Mosses and liverworts.
III. Pteridophyta	Ferns and their allies.
IV. Spermatophyta	The spermatophytes or seed plants.

We are concerned here with the Spermatophyta only and this group or subcommunity is divided into two divisions, with subdivisions as follows:

Division I. *Gymnospermae:* ovules naked, not enclosed in an ovary.
Division II. *Angiospermae:* ovules in a carpel or ovary.
  Class I. Monocotyledoneae: one seed leaf.

Class II. Dicotyledoneae: two seed leaves.
  Series I. Choripetalae: petals (or sepals) distinct or separate.
  Series II. Gamopetalae: petals (or sepals) united.

No vegetables belong in the division *Gymnospermae*, so we are concerned only with the second division—*Angiospermae*.

The class, family, genus, species, and subspecies or botanical variety to which vegetables belong are as follows:

Monocotyledonae		
Gramineae—Grass Family		
Zea Mays	var. *rugosa*	Sweet corn
Zea Mays	var. *everta*	Popcorn
Lilaceae—Lily Family		
Allium Cepa		Onion
Allium Cepa	var. *solanium*	Multiplier onion
Allium Cepa	var. *viviparum*	Top onion or tree onion
Allium Porrum		Leek
Allium sativum		Garlic
Allium fistulosum		Welsh onion
Allium ascalonicum		Shallot
Allium Schoenoprasum		Chive
Asparagus officinalis	var. *altilis*	Asparagus
Dicotyledoneae		
Polygonaceae—Buckwheat Family		
Rheum Rhaponticum		Rhubarb
Rumex Acetosa		Sorrel
Rumex Patientia		Patience or dock
Chenopodiaceae—Goosefoot Family		
Chenopodium Bonus-Henricus		Good-King-Henry
Beta vulgaris		Beet
Beta vulgaris	var. *Cicla*	Chard
Atriplex hortensis		Orach
Spinacia oleracea		Prickly-seeded spinach
Spinacia oleracea	var. *inermis*	Round-seeded spinach
Aizoaceae—Carpetweed Family		
Tetrogonia expansa		New Zealand spinach
Mesembryanthemum crystallinum		Ice plant
Cruciferae—Mustard Family		
Brassica oleracea	var. *acephala*	Kale
Brassica oleracea	var. *gemmifera*	Brussels sprouts
Brassica oleracea	var. *capitata*	Cabbage
Brassica oleracea	var. *botrytis*	Cauliflower, broccoli
Brassica oleracea	var. *italica*	Sprouting broccoli
Brassica caulorapa		Kohlrabi
Brassica Napus		Rape
Brassica Napobrassica		Rutabaga
Brassica Rapa		Turnip
Brassica juncea		Leaf mustard
Brassica juncea	var. *crispifolia*	Curled mustard and others
Brassica pekinensis		Pe-tsai Chinese cabbage
Brassica chinensis		Pakchoi Chinese cabbage

Barbarea vulgaris		Upland cress
Roripa Nasturtium-aquaticum		Water cress
Armoracia rusticana		Horse-radish
Lepidium sativum		Garden cress
Rhaphanus sativus		Radish
Rhaphanus sativus	var. *longipinnatus*	Chinese radish
Crambe maritima		Sea kale
Leguminosae—Pea or Pulse Family		
Pisum sativum		Pea
Pisum sativum	var. *humile*	Early dwarf pea
Pisum sativum	var. *macrocarpon*	Edible-podded pea
Vicia Faba		Broad bean
Phaseolus vulgaris		Pole bean
Phaseolus vulgaris	var. *humilis*	Bush bean
Phaseolus coccineus		Multiflora or scarlet runner bean
Phaseolus lunatus		Sieva bean
Phaseolus limensis		Lima bean
Phaseolus limensis	var. *limenanus*	Bush lima
Phaseolus Mungo		Urd bean
Phaseolus aureus		Mung bean
Phaseolus angularis		Adzuki bean
Phaseolus calcaratus		Rice bean
Phaseolus aconitifolius		Moth bean
Phaseolus acutifolius	var. *latifolius*	Tepary bean
Vigna sesquipedalis		Asparagus or yard-long bean
Vigna sinensis		Cowpea
Glycine Max (*Soja Max*)		Soybean
Malvaceae—Mallow Family		
Hibiscus esculentus		Okra
Umbelliferae—Parsley Family		
Daucus carota	var. *sativa*	Carrot
Petroselinum hortense		Parsley
Petroselinum hortense	var. *radicosum*	Hamburg or root parsley
Apium graveolens	var. *dulce*	Celery
Apium graveolens	var. *rapaceum*	Celeriac
Pastinaca sativa		Parsnip
Sium Sisarum		Skirret
Anthriscus Cerefolium		Chervil
Convolvulaceae—Morning Glory Family		
Ipomoea Batatas		Sweet potato
Solanaceae—Nightshade Family		
Solanum tuberosum		Potato
Solanum melongena	var. *esculentum*	Eggplant
Solanum melongena	var. *serpentinum*	Snake eggplant
Solanum melongena	var. *depressum*	Dwarf eggplant
Lycopersicon esculentum		Tomato
Lycopersicon esculentum	var. *cerasiforme*	Cherry tomato
Lycopersicon esculentum	var. *pyriforme*	Pear tomato
Lycopersicon esculentum	var. *commune*	Common tomato
Lycopersicon esculentum	var. *grandifolium*	Potato-leaved tomato

Lycopersicon esculentum	var. *validum*	Upright tomato
Lycopersicon pimpinellifolium		Currant tomato
Physalis pubescens		Husk tomato
Capsicum frutescens		Pepper
Capsicum frutescens	var. *cerasiforme*	Cherry pepper
Capsicum frutescens	var. *conoides*	Cone pepper
Capsicum frutescens	var. *fasciculatum*	Red cluster pepper
Capsicum frutescens	var. *longum*	Long pepper
Capsicum frutescens	var. *grossum*	Bell or sweet pepper
Martynaceae—Martynia Family		
Proboscidea Jussieui (Keller)		Martynia
Cucurbitaceae—Gourd Family		
Cucurbita pepo		Pumpkin
Cucurbita pepo	var. *condensa* (Bailey)	Bush pumpkin (Summer squash)
Cucurbita moschata		Pumpkin (cushaw and large cheese)
Cucurbita maxima		Squash
Citrullus vulgaris		Watermelon
Cucumis sativus		Cucumber
Cucumis Melo		Muskmelon
Cucumis Melo	var. *reticulatus*	Netted melons
Cucumis Melo	var. *cantalupensis*	Cantaloupes
Cucumis Melo	var. *inodorus*	Cassaba melon
Cucumis Melo	var. *Chito*	Mango melon or lemon cucumber
Sechium edule		Chayote
Compositae—Composite Family		
Cichorum Intybus		Chicory
Cichorum Endivia		Endive
Scolymus hispanicus		Spanish salsify
Scorzonera hispanica		Black salsify
Tragopogon porrifolius		Salsify
Taraxacum officinale		Dandelion
Latuca sativa		Lettuce
Latuca sativa	var. *crispa*	Curled lettuce
Latuca sativa	var. *capitata*	Head lettuce
Latuca sativa	var. *longifolia*	Cos lettuce
Latuca sativa	var. *angustana*	Asparagus lettuce
Helianthus tuberosus		Girasole or Jerusalem artichoke
Cynara Cardunculus		Cardoon
Cynara Scolymus		Artichoke

Classification Based on Hardiness.—Vegetables are often classified as "hardy" and "tender." Those classed as hardy will endure ordinary frosts without injury, while those classed as tender would be killed. This implies that frost injury is the chief difference between hardy and tender plants, but there are other distinctions. Some of the hardy plants will not thrive well under hot dry conditions so that in the North they should be planted early in the spring or late in the summer. Others will withstand frost and also thrive during hot weather of summer. Some tender vegetables do not thrive in cool weather even if no frost occurs. The terms "cool-season" and "warm-season" crops are used to suggest conditions under which the crops thrive best, rather than their susceptibility to frost injury.

Based on the temperature that the plants will withstand, some vegetable plants are hardy, some semihardy, others tender, and still others very tender. The hardy ones may safely be planted before the date of the last killing frost in spring. The semihardy will not stand a hard frost but will grow in cool weather and are not injured by a light frost. The tender plants are injured or even killed by a light frost, but can withstand cool weather and a cold soil, while the very tender are injured by cool weather. This system of classification is of some value in connection with a discussion of time of planting. By grouping all hardy plants together general principles regarding time of planting can be given for the whole group. The semihardy, tender, and very tender plants may be grouped in the same way for discussion. This system is used in Chap. IX.

Classification Based on Parts Used as Food.—In this system of classification those crops grown for their leaves or stems are placed in one group. This group includes cabbage, kohlrabi, collards, asparagus, rhubarb, all of the salad crops, and all of the potherbs or greens. A second group includes those crops grown for their fruits, as melons, tomatoes, eggplants, beans, peas, etc., while a third group includes those grown for their flower parts, as cauliflower and broccoli. Those crops grown for their underground portions (roots, tubers, bulbs, and corms), as potato, sweet potato, beets, carrots, parsnips, radish, turnip, salsify, onions, garlic, dasheen, and many others, constitute a fourth group. In each of these groups the crops cover a great range of cultural requirements so that grouping them in this way is not of much value.

Classification Based on Methods of Culture.—A system of classification based on essential methods of culture is very convenient. In this system all those crops which have similar cultural requirements are grouped together for discussion. This makes it possible to give the general cultural practices for the group without the necessity of repetition in the discussion of individual crops. This system combines some parts of the other three methods. In some of the groups, as cucurbits, beans and peas, bulb crops, and cole crops, all crops considered in each belong to the same family. In other groups as perennial crops, potherbs and greens, salad crops, and the root crops, more than one family is represented in each group. In the perennial-crops group of six vegetables, five families are represented.

In teaching principles of vegetable gardening this system of classification has been found more satisfactory than any other and is followed in a general way in this book. In some of the groupings the crops within a group do not have much in common, but they are placed together for convenience. The vegetables discussed are placed in twelve groups and the discussion for each group constitutes a chapter. The grouping is as follows:

- Group 1. Perennial Crops.
  - Asparagus, Rhubarb, Artichoke, Jerusalem Artichoke, Sea Kale, Udo.
- Group 2. Potherbs or Greens.
  - Spinach, New Zealand Spinach, Orach, Kale, Chard, Mustard, Collards, Dandelion.
- Group 3. Salad Crops.
  - Celery, Lettuce, Endive, Chicory, Cress, Corn Salad, Parsley, Salad Chervil.
- Group 4. Cole Crops.
  - Cabbage, Cauliflower, Broccoli, Brussels Sprouts, Kohlrabi, Chinese Cabbage.
- Group 5. Root Crops.
  - Beet, Carrot, Parsnip, Turnip, Rutabaga, Salsify, Turnip-rooted Chervil, Skirret, Radish, Horse-radish, Scorzonera or Black Salsify, Scolymus or Spanish Salsify.
- Group 6. Bulb Crops.
  - Onion, Leek, Garlic, Shallot, Ciboul (Cibol), or Welsh Onion, Chive or Cive.
- Group 7. The Potato.
- Group 8. The Sweet Potato.
- Group 9. Peas and Beans.
  - Pea, Bean, Broad Bean, Common or Garden Bean, Multiflora Bean, Sieva and Lima Beans, Tepary Beans, Soybean, Cowpea.
- Group 10. Solanaceous Fruits.
  - Tomato, Eggplant, Pepper, Husk Tomato or Physalis.
- Group 11. The Cucurbits.
  - Cucumber, Gherkin, Muskmelon, Watermelon, Citron Melon, Pumpkin, Squash.
- Group 12. Sweet Corn, Okra, Martynia.

CHAPTER III

SOILS AND SOIL PREPARATION

The soil is the storage house for certain elements and compounds use by plants, as well as the home of their roots. Therefore, the physica and chemical composition of the soil is of prime importance in cro production. The chemical composition can be changed by adding fertilizers and other materials and to some extent by drainage and tillag which favor aeration. The physical condition of the soil is improved b drainage, by tillage, and by incorporating organic matter. Unless th soil is in good physical condition large yields cannot be secured. Fertilizers, good seed, and the best of care will not insure success unless th soil is of good texture and is well prepared.

CLASSIFICATION OF SOILS

Soils are classified in various ways and there are many divisions, bu only the soil type and the soil class are considered here.

For technical discussions of soils and their classification the reader i referred to textbooks on the subject.

Soil Type.—A soil that has relatively uniform profile characteristi represents a soil type. Any particular soil of a series is designated by it textural name, as sandy loam, clay loam, or silt loam; before the textura name is added the series name. The type name is, therefore, made u of two parts, the first designating the series and the second the individua within the series, as, for example, sassafras silt loam, Dunkirk clay loam Norfolk sandy loam. The first word in each of these names designate the series and the others the textural grade or class. All of them take together make the name of the soil type.

Soil Class.—The soil class, or textural grade, is a classification base on texture alone. Texture is a term used to indicate the coarseness c fineness of the soil; the textural composition is determined by a mechanical analysis, which is a laboratory process. The system used by th U. S. Department of Agriculture separates the soil particles into seve sizes as follows:

Name of Soil	Size, Mm.
Fine gravel	2 to 1
Coarse sand	1 to 0.5
Medium sand	0.5 to 0.25
Fine sand	0.25 to 0.10

Name of Soil	Size, Mm.
Very fine sand	0.10 to 0.05
Silt	0.05 to 0.005
Clay	0.005 and below

Soils are separated into three groups: sandy soils, loamy soils, and clayey soils, determined by the proportion of the several sizes given above. Sandy soils include gravelly sands, coarse sands, medium sands, fine sands, and very fine sands. Loamy soils include coarse sandy loams, medium sandy loams, fine sandy loams, very fine sandy loams, silt loams, silty clay loams, and clay loams. Clayey soils include gravelly clays, sandy clays, clays, and heavy clays.

All classes of soils are used to some extent for vegetable production and, while no one class can be said to be the best, each class has its advantages and disadvantages. One class may be very desirable for crops grown under certain conditions, but undesirable for the same crops grown under other conditions or for other crops. The soil classes preferred for vegetable production are sandy soils, sandy loams, silt loams, clay loams, and muck or peat soils.

Sandy Soils.—A sandy soil is single grained and the individual grains can be seen and felt readily. Soils classed as sandy contain less than 15 per cent of silt or clay. The different classes of sandy soils are determined on the basis of the proportion of the various sand separates making up the soil. When wet a sandy soil can be formed into a ball, but it will crumble readily if touched.

Sandy soils are known as early soils because they dry out early in the spring and warm up sooner than do those made up of a larger proportion of silt or clay. Sandy soils are naturally infertile and are not retentive of moisture. They are considered of value for very early crops, but they are not suited to long-season crops or those grown during the warmest part of the growing season. The finer grained sandy soils are used extensively for growing vegetables. The moisture-holding capacity of sandy soils can be increased by adding organic matter in the form of manure, crop residues, or soil-improving crops.

Sandy Loams.—A sandy-loam soil contains much sand but has enough silt and clay to make it hold together somewhat. When moist, a sandy loam can be formed into a cast that will bear careful handling without breaking. Sandy loams contain from 20 to 50 per cent of silt and clay. The four classes of sandy loams are separated on the basis of the percentages of the various separates from fine gravel to very fine sand.

Sandy loams are more retentive of moisture and of nutrients than are the sands and, in general, are considered better for vegetable growing. They are not so early as the sandy soils, but are earlier than the loams, silt loams, clay loams, or clays. Both the sandy and sandy-loam soils may be worked soon after a rain or after irrigation without injury; this is a great advantage in early preparation of the soil and in keeping weeds under control by cultivation.

LOAM SOILS.—A loam is a soil having a relatively even mixture of different grades of sands and of silt and clay. Loams contain less than 20 per cent of clay, from 30 to 50 per cent of silt, and from 30 to 50 per cent of sand.

SILTY LOAMS.—These soils contain less than 20 per cent of clay, 50 per cent or more of silt, and less than 50 per cent of sand. When dry silt loam breaks up, it is cloddy or lumpy, but the lumps can be broken down readily, and when pulverized it feels smooth and soft. When wet a silt-loam soil runs together, and, when either wet or dry, it will form a cast if squeezed. They are valuable for the production of most kinds of vegetables, especially where large yields are more important than earliness. These soils are naturally more fertile and more retentive of moisture than are the sands or sandy loams. Silt loams are considered by many as one of the best classes for general vegetable growing.

CLAY LOAMS.—These soils contain from 20 to 30 per cent of clay. A soil in this group that contains less than 30 per cent of silt and from 50 to 80 per cent of sand is called a sandy clay loam; one with from 20 to 50 per cent of silt and from 20 to 50 per cent sand is known as clay loam; while one containing from 50 to 80 per cent of silt and less than 30 per cent sand is known as silty clay loam. A clay loam usually is fine textured and breaks up into clods that are hard when dry. Clay loams are more retentive of moisture than are the soils of coarser texture, but they are difficult to prepare and are not considered so good for early crops. These soils can be improved by the addition of organic matter and to some extent by liming. Clay loams are not desirable for small-growing vegetable crops and are particularly objectionable for root crops.

PEAT AND MUCK.—Peat and muck are composed largely of different kinds of plants at various stages of decomposition. The terms "muck" and "peat" are often used indiscriminately to designate soils that are composed largely of organic matter. In some regions all organic soils are called peat, while in other regions all such soils are termed muck. Wilson (1935) states that there are two methods of differentiating them. One is based on the percentage of organic matter the soil contains and the other is based on the extent of decomposition. In the first case, if the soil contains as much as 50 per cent of organic matter it is called peat, while if it contains less than that it is called muck. By the second method, the soil is classed as muck if decomposition has advanced so far that the structure of the organic residues is no longer evident; otherwise it is called peat. Wilson states that according to each of these classifications practically all of the organic deposits of New York are peats. It is probable that most of the organic deposits in the United States should be called peats under either of these classifications. However, in this discussion the term muck is generally used and refers to any organic soil that is used or may be used for vegetable growing. The term muck, as used here, should not be confused with those mineral soils of a muck nature that contain considerable humus, but that are not combustible.

The chief characteristics of muck are:

1. It is predominately high in organic matter, containing 50 to 85 per cent combustible material when dry.
2. It is brown or black in color, and the more advanced the stage of decomposition the darker the color.
3. It has a high water-holding capacity, absorbing 60 to 85 per cent of its volume and 300 to 1,000 per cent of its weight of water.
4. It is generally rich in nitrogen. Most of the muck soils that are under cultivation contain from 1½ to 2½ per cent of nitrogen in organic form. Many deposits contain much more than this.
5. Muck is usually low in mineral elements, especially potash. All deposits that have been tested are poor in potash, which is the main limiting factor. Some deposits are deficient in phosphorus as well as potash.
6. Muck is a late soil because of its high water-holding capacity and it is subject to late frosts in spring and early frosts in fall.

For the production of certain vegetables, especially celery, lettuce, and onions, muck soils are considered better than any others; a large portion of them in the North is produced on muck soils. Carrots, beets, parsnips, spinach, cabbage, potatoes, and other vegetables are grown to some extent on muck soils. The principal advantages of such soils over other kinds are as follows: (1) they are rich in nitrogen, (2) they have a high water-holding capacity, (3) they do not bake as readily as soils containing considerable clay, and (4) they are loose and friable thus being easy to work soon after rains; because of the friable nature, root crops grown on them are straight and symmetrical.

Muck soils are not suitable for the growing of tender, long-season crops because frosts are likely to occur later in the spring and earlier in the fall on these soil than on mineral soils. It has been assumed that this is due largely to the low elevation of the muck, but it has been observed that crops are sometimes injured by frost on muck soils and not on mineral soil at approximately the same elevation. Results of studies made by Bouyoucos and McCool (1922) give the reasons for this. They made temperature studies on clay loam and muck placed at the same elevation. Their results indicate that heat moves more rapidly through a clay loam than through a muck soil; therefore, at night the air above the clay loam has a higher temperature than that above muck. McCool and Harmer (1925) comment as follows on the results of those studies:

During the early part of the day the clay loam absorbed heat more rapidly than did the muck, but by late afternoon the muck had become nearly as warm as the mineral soil even to the depth of 6 inches. On a clear, cool night which followed, heat was lost from both soils by radiation. The temperature of the cultivated muck soil dropped 8° more than that of the mineral soil, reaching a temperature 4° below the freezing point of water. At a depth of 6 inches, however, the temperature of the mineral soil dropped 5° more than did that of the muck soil. In other words, sufficient heat moved from below to the surface of the mineral soil to keep the surface from freezing. The muck soil was such a poor conductor that the heat below did not move up, consequently the surface layer and the air just above it were cooled to a point at which a crop would have been frosted. The compact muck soil was a better conductor of heat than was the cultivated muck, with a result that the surface temperature dropped to only 1° below freezing. Further, the muck with a light covering of sand gave an even smaller drop in temperature at the surface than did the compact muck.

The "frostiness" of a muck depends on several factors, of which the following are most important: (1) moisture content, (2) compactness, (3) state of decomposition, (4) content of mineral matter, (5) fertilization.

Heat moves up from below to the surface more rapidly in a moist than in a dry muck. If the soil is compact, the movement of heat takes place still more readily. For that reason the heavy roller is a valuable implement in aiding the prevention of frosts. The looser the surface layer, the greater the danger of summer frosts. Frequently when a field of corn or potatoes on muck has been partly cultivated before a frost occurred, the cultivated portion has been frosted while the uncultivated part has escaped. The loose cultivated layer serves as a blanket to keep the heat in the soil so that the air just above it is not kept warm.

Ordinarily the more decomposed a muck becomes, the smaller becomes the probability of frost occurrence. For that reason, old mucks are generally not as "frosty" as those recently reclaimed. A soil fairly high in mineral matter is likewise not as subject to frost as one that is low in these constituents.

Not all mucks are valuable for vegetable growing. Their value depends on the stage of decomposition, the character of the material from which the soil was formed, the drainage, the location, and other factors. In general, the more decomposed the material the better the muck for vegetable growing. It is believed by many authorities that muck soils which have supported a growth of deciduous trees and shrubs are better than those which have grown coniferous trees. A peat which contains a large quantity of material from coniferous trees decomposes more slowly than one which does not contain such material. This is probably due to the resins in the conifers, which preserve the woody materials. Some muck soils are toxic, usually on account of the underlying rock and are nearly useless for growing vegetables. Others are unproductive because of a deficiency of certain elements not commonly supplied in the usual mixed fertilizers. Reference is made in Chapter VI to the remarkable effects of copper on crop growth when applied to the saw-grass peat soils of the Florida Everglades, and to certain unproductive muck areas found in western New York.

Drainage and tillage are important factors in the decomposition of the organic material in muck soils. Removing the water and stirring the soil allow air to enter and favor the growth of organisms that cause the breaking down of the plant remains. Oxidation itself is of importance. Lime also favors decomposition when the soils are sour for the desirable organisms do not thrive well in a very acid soil. Stable manure has been found to be very beneficial on newly cleared muck soils because of the presence of beneficial organisms in the manure. Manure may therefore be considered as an inoculant or at least a carrier of beneficial organisms.

For the first few years after muck is cleared it is advisable to grow some general farm crop, such as corn or hay, rather than vegetables. The latter do not thrive well on new muck and the roots and trash interfere with planting, cultivating, and harvesting the more intensively cultivated vegetables. Two or three years of tillage will usually put most muck soils in good condition for onions, celery, and lettuce.

IMPORTANCE AND DISTRIBUTION OF MUCK.—It has been estimated that there are approximately 138,000 square miles or nearly 90,000,000 acres of swamp land in the United States, a large part of which is muck or peat. The muck and peat deposits are more abundant in the Northeast than in other sections of the country. The main deposits are north of a line extending westward from about the southern boundary of New York nearly to the ninetieth meridian.

Florida probably has a greater acreage of peat soil than any other state, with Minnesota, Michigan, and Wisconsin following in this order. Other deposits are found in a narrow strip along the Atlantic coast from Maine to Florida, and in many other states, including Indiana, California, Oregon, Washington, Iowa, and New York. Small deposits are found in other states but they are not of great importance. Only a small part of the peat lands of the United States is cleared and most of this is used for general farm crops and for pasture. This is as it should be for if 2 per cent of the peat-land acreage was planted to the vegetable crops commonly grown on such land there would be serious overproduction with resultant low prices for the products.

SOIL PREPARATION

Thorough preparation of the soil is essential to successful production of nearly all farm crops and is especially important in the growing of vegetables. Poor preparation usually results in an inferior stand of plants regardless of the quality of the seed and no amount of after cultivation will take the place of good preparation. Among the operations considered are drainage, plowing, harrowing, dragging, and rolling. Clearing the land might be considered also, and, in irrigated regions, leveling undoubtedly would be considered as a part of preparation but these are not considered here.

Drainage.—For wet soils the first operation in the preparation should be drainage as most soils cannot be properly prepared when poorly drained. Good drainage is essential to success in growing practically all vegetables, although some crops stand wet soils better than others, and a few minor ones, such as water cress, thrive in a very wet soil. Good drainage is especially important for early vegetables because earliness is not possible in a wet soil. The sands are of value in growing early vegetables because they are better drained than the heavier soils. On soils not naturally well drained artificial drainage is a profitable investment. It is much better to drain the soil by means of ditches or tiles than to plant the crop on ridges. Drainage not only removes the excess water, but also allows the air to enter the soil and air is essential to the growth of beneficial organisms which make some of the nutrients available to the plants. Drainage also allows the soils to warm earlier in the spring, thus favoring early preparation and planting.

Special attention should be given to the drainage of peat soils. Without drainage, the natural water level ordinarily is too high for most farm and vegetable crops. On the other hand, overdraining is not uncommon and this is as objectionable as underdraining. When an overdrained muck becomes very dry it may require considerable rain to restore its normal moisture content. Where areas have been overdrained the condition can be remedied by the use of dams placed in the outlet ditches to raise the water level.

McCool and Harmer (1925) suggest a ground-water level during the summer of about 3 feet below the surface for most general farm crops and root crops, although it may be higher during the early part of the season. If the material is raw and fibrous, the water level should be nearer the surface, while if it is compact and contains considerable clay it may be lower than the distances given. The need is for a drainage system adequate to remove the excess water within a few hours following a heavy rain, without resulting in excessive drainage at other times.

The drainage of many muck deposits is by means of open ditches, but tile is used in some cases for the laterals and submains. Tile has proved very satisfactory where it has been laid properly. The use of tile results in the saving of land area, avoids cutting up the fields by ditches, saves labor by eliminating the necessity of cleaning ditches and cutting weeds on the ditch bank, and does away with a source of supply of weed seed.

Since new muck settles rapidly after it is cleared, drained, and put under cultivation, it is considered wise to use open ditches for a few years and then to use tile where it can be employed satisfactorily. At the University of Wisconsin it was found that the muck settled about 9 inches in 5 years after the tile had been laid 3½ feet deep. When muck has settled for a few years, tile laid at a depth of 3 or 3½ feet will lower the water sufficiently for most crops.

The distance that should be allowed between parallel lines of tile depends on the rainfall, the type of muck, and the nature of the underlying material. The greater the rainfall, the closer the lines of tile should be. Where the muck is deep or is underlaid with clay or marl, lines of tile or ditches must be much closer than when the muck is underlaid with sand or gravel. The distance between lines of tile or open ditches varies from 50 feet in an impervious type of muck to as much as a ½ mile in an open type of muck underlaid with sand or gravel at a depth penetrated by the main ditches.

Plowing.—Soils for vegetables should be fairly deep, but a shallow surface soil should be deepened gradually. A soil that has been plowed only a few inches deep should be deepened by increasing the depth an inch or two a year until the desired depth is reached. Too much of the subsoil turned to the surface usually is injurious. A depth of 6 to 8 inches is sufficient on most soils. In years past it has been thought that the deeper the land was plowed, the better it was for crop production, provided too much raw subsoil was not turned to the surface at once, but experimental results do not indicate that this is true. The roots of most plants go below the depth plowed.

The time for plowing depends somewhat on the kind of soil and on the climatic conditions. Fall plowing is desirable on all soils where it can be practiced and especially where sod is to be turned under. The advantages of fall plowing are: (1) to reduce erosion by collecting water in the unbroken furrows, (2) to improve the physical condition of heavy soils by exposing them to frost action, (3) to aid in the control of insect pests by exposing them to the weather, (4) to relieve the pressure of spring work, (5) to make possible the earlier preparation of the soil for planting, (6) to bring about the decay of coarse vegetable matter turned under. Coarse material turned under in the spring is of little value to early crops and may be actually injurious as mentioned in Chap. IV. Fall plowing in the South is not so desirable as in the North due to the loss by leaching where the soil does not freeze. In the South the effects of freezing and of alternate freezing and thawing are not so important as in the North. Where shallow plowing is practiced, as in many regions of the South, fall plowing is not desirable, especially on hilly land, because the whole furrow slice often slides down the hill and leaves the subsoil exposed. Sandy or sandy loam soils are not so much benefitted as clay soils by fall plowing even in the North because frost action is not especially important on soils that are naturally friable.

Spring plowing should be done as early as the soil will permit, but great care should be exercised not to plow when the land is too wet. This is especially important on clay soils. No soil containing a considerable portion of clay should be plowed when wet nor should such a soil be allowed to get too dry before plowing. If plowed too wet such soils will puddle and bake and will be very difficult to get into good condition. If allowed to get too dry, clayey soils break up in hard lumps which are difficult to pulverize by harrowing. A soil is in good mechanical condition for plowing if after being compacted in the hand it gradually crumbles when the pressure is released. If it is moist enough to retain its form after the pressure is released it is too wet for plowing.

Harrowing.—After spring and summer plowing the ground should be harrowed as soon as possible to make the surface loose and friable. The condition of the soil should determine the type of harrow to use. A disk harrow is especially valuable on heavy clay soils and on sod land because it thoroughly pulverizes the soil to a considerable depth. After disking, the soil is usually smoothed by a spike-tooth, Acme, or spring-tooth harrow. The first is satisfactory for leveling and smoothing the surface but is a poor implement for pulverizing the soil as the teeth do not go deeply enough and clods and lumps pass between the teeth. The last is an important implement on stony ground; it is a good pulverizer and leveler. The Acme harrow is good because it not only pulverizes the soil to a considerable depth, but also leaves the surface smooth; it is not satisfactory on stony ground. The Meeker smoothing harrow is almost indispensible in intensive gardening as a finishing harrow. It is not at all satisfactory for anything except to fine and smooth the surface, but should be in more general use for this purpose. The Meeker leaves the surface in as good condition as a garden rake and is much more economical. It pulverizes the soil to the depth of 2 or 3 inches, breaks up the smallest clods, and by means of an adjustable board across the middle it levels the soil and leaves it in a smooth condition. This harrow is often used just before seed sowing and transplanting.

The thoroughness with which the soil is prepared before planting determines to a large extent the ease and efficiency of cultivation, but no amount of cultivation will make up for poor preparation. Timeliness is of the greatest importance in all operations concerned with soil preparation and cultivation. The moisture content of the soil determines to a considerable extent the efficiency of the work done by the harrow. If the soil is too dry, a large percentage of lumps will not be crushed and if too wet the soil will become puddled. Harrowing the soil almost immediately after plowing will prevent surface baking and may reduce the loss of moisture by evaporation and by the growth of weeds.

Dragging and Rolling.—Heavy soils often break up in clods and lumps that are very difficult to crumble with any type of harrow. By use of a heavy drag or roller the lumps may be crushed with comparative ease. In preparing the soil late in the season, the drag often is used immediately after the plow, and then followed with the disk or spring-tooth harrow. In some instances the drag or roller is used before and after the harrow in order to crush the lumps brought to the surface by the harrow. The main use of the drag or roller on heavy soils is to crush the lumps, but on light soils both are often used to pack and smooth the soil. On muck soil the usual practice is to use a drag or planker, as it is often called, just before planting in order to level and smooth the surface. In this case the drag need not be so heavy as when used for lump crushing, unless packing of the soil is also an important consideration.

CONTROL OF SOIL EROSION

Soil erosion by water and by wind is a serious matter in many vegetable-growing regions. Water erosion is prevalent in all rolling and hilly regions where there is sufficient rainfall to cause erosion, but is perhaps most severe in regions of high rainfall and hilly land in the South. Wind erosion is most severe in the Great Plains area, but is important on muck soils and on sandy soils in many vegetable-growing regions of the United States.

Water Erosion.—Soil erosion by water can be controlled by terracing the land, by contour tillage and planting, and by strip cropping. Growing a cover crop on the land when it is not producing a crop to be harvested and keeping the soil well supplied with humus also aid in the control of erosion.

By the use of terraces, the land is divided into separate drainage areas with each area having its own waterway above the terrace. The terrace holds the water on the land, thus allowing it to soak into the soil, and reducing or preventing gulleying. The terraces follow the contour of the land and should be made broad and of low grade to allow the water to move slowly.

In contour farming, row crops are planted on the contour so that they can be cultivated on the level rather than up and down the slope or at right angles to it. Contour cultivation conserves moisture and reduces erosion by holding the water in the little terraces made by the cultivator until it soaks into the soil.

Strip cropping consists of growing crops in narrow strips across the slope usually on the contour. The strips are planted to a series of crops so that sod crops and other noncultivated crops are placed between strips of intertilled crops. The areas of noncultivated crops usually take up the rains that fall on them and also the runoff from the cultivated strips and thus prevent serious erosion. The width of the cultivated strips is determined by the steepness of the slope, the rate of percolation of water into the soil, the absorptive capacity of the soil, and the rainfall. Obviously the steeper the slope the narrower the strips should be.

Wind Erosion.—Soil erosion by wind can be controlled by the use of windbreaks of various kinds, by keeping the soil well-supplied with humus, and by growing cover crops when the land is not occupied by other crops. In the growing of small-growing crops on muck soils it is necessary to use windbreaks of some kind unless the land is protected by hills or by natural growth of trees and other vegetation. Protection against wind injury is desirable also on very light sandy soils.

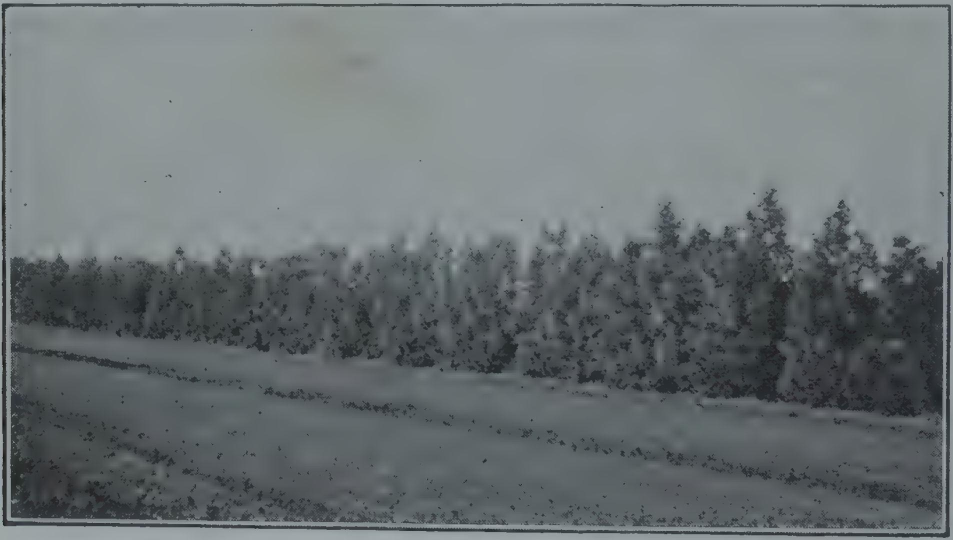

FIG. 1.—Cedar windbreak on a New York muck farm.

The types of windbreaks that are in use on muck soils are: (1) trees, (2) shrubs, (3) fences of boards, slats, or cloth of some kind, and (4) plantings of grain or forage crops.

The trees most commonly planted as windbreaks are box elder, willow, poplar, Norway spruce, and white cedar. The large-growing trees such as the poplars and some of the willows are planted only along roadways and along large ditches as they utilize too much land when planted in cultivated areas. Small-growing willows and other trees that can be kept in bounds by pruning are planted in single rows at somewhat regular intervals through the fields that are subject to wind erosion. In some areas, rows of basket willows are planted about 200 to 300 feet apart and in other cases, rows of white cedar trees (Fig. 1) are planted about the same distance apart. Hedges of privet make good windbreaks where the plants are not winterkilled. Such hedges are used on sandy soils in some areas and, if placed properly, give good protection.

Objections to the planting of trees as windbreaks are that they occupy a considerable area of land and that they are not effective until they have had a few years growth. These two objections have led many muck-land vegetable growers to use fences of various kinds. Solid board fences 4 to 6 feet high are used in some regions, especially where small areas are operated by individual farmers. Slat fences, similar to snow fences, are more common than the solid board fences, since they do not cost so much and can be removed easily.

Corn, small grains, and some of the hay crops are used as windbreaks on muck soil in several states. Harmer (1929) mentioned white sweet clover and alfalfa as crops that give protection, and states that the place for these is along the ditch bank where their rapid growth in spring serves to smother weeds and to prevent wind injury for some distance. Corn has been used in some of the smaller muckfields according to Harmer. It is planted in single rows, the ears are harvested in the fall, and the stalks allowed to stand during the following summer. Where the European corn borer is a serious pest, leaving the old corn stalks standing in the field would be objectionable.

Of the small grains, rye is the best crop under most conditions, but oats and barley and spring wheat are satisfactory for planting early in the spring. Where rye is sown as a cover crop in the fall a strip a foot or more in width may be left every 50 or 60 feet; this will give protection before spring planted grains would be well started. This method is followed by some muckland farmers in New York. On one large farm hedges of willows are planted about 200 feet apart at right angles to the direction of the prevailing wind and between these at intervals of about 50 feet, strips of fall-sown rye are left. Another method of using small grains is to sow a row of grain between rows of crops. In some cases one row of grain is sown between every three to six rows of onions or other crops given similar spacing, but where wind damage is severe, a row of barley or other grain is planted for each row of onions. When onions or other crops are planted very early in the spring, the grain should be sown at the same time, but for crops planted later the grain crop should be sown a week or two before the vegetable crop is to be planted. After the vegetable crop has reached sufficient size to need no protection the grain plants should be removed to prevent shading the vegetable plants and to eliminate the competition for moisture and nutrients.

For a more complete discussion of erosion control the reader is referred to "Conservation of the Soil" by Gustafson, published by McGraw-Hill Book Company, Inc., New York.

CHAPTER IV

MANURES

Stable manure, or barnyard manure, was practically the only fertilizing material applied to the soil in the early days of commercial vegetable growing in the United States. With the large increase in acreage of vegetables during recent years and with a marked decline in the number of horses kept in the cities, the supply of manure is inadequate to meet the needs of even the near-by market gardeners. It is evident that the greatest economy in the care and use of manure should be practiced. It is also evident that substitutes must be used to supply both humus-forming materials and the so-called fertilizing elements or nutrients.

One of the greatest problems confronting vegetable growers is the maintaining of production with less manure, or without manure. The difficult part of this problem is to supply the humus in sufficient quantity. The mineral nutrients can be supplied in good form and at a relatively low price in commercial fertilizers, but the humus supply must be grown. Vegetable growers producing crops on high-priced land must follow intensive cropping systems, which give relatively little time for growing soil-improving crops. This is the main reason that market gardeners have depended on manure, but it is perfectly clear that in the future more dependence must be placed on soil-improving crops and commercial fertilizers.

The problem can be and is being met in the following ways: (1) by growing vegetables on cheaper land at greater distances from the market and depending largely on soil-improving crops and commercial fertilizers, (2) by using less manure per acre and supplementing it with commercial fertilizers and soil-improving crops, and (3) by using the manure on crops needing it most. Where land is relatively cheap it can be used during a part of each season for growing crops to turn under. Even under the most intensive systems of gardening some soil-improving crops can be grown. By turning under sufficient humus-forming material and supplying the necessary nutrients, production can be maintained with most crops without manure, provided other factors are favorable. This is discussed more fully in Chap. V.

Manure is of value as a source of humus, as a carrier of nutrient elements, nitrogen, phosphorus, and potash and as a carrier and promoter of useful organisms. Manure aids in making available some of the mineral elements in the soil and carries appreciable quantities of some of the minor or trace elements.

Manure as a Source of Humus.—Vegetable growers would not be justified in buying manure at the present prices for the nitrogen, phosphorus, and potash it carries. These elements can be purchased more cheaply in chemical fertilizers, especially when the cost of hauling and applying are taken into consideration. Manure is one of the most valuable humus-forming materials and some form of organic matter is necessary to keep the soil in good condition for crop growth. The organic matter improves heavy soils by making them looser and more friable, thus improving their drainage, increasing aeration, and making them easier to work. It also tends to make heavy soils warm up earlier in the spring. It improves light soils, as sandy and sandy loams, by filling the spaces between the grains with humus thereby making them less porous and more retentive of moisture and nutrients. Heavy applications of manure made to sandy soils enable vegetable growers to produce large yields—a result impossible without manure or some other source of humus. It is as a source of humus that manure has its greatest value for the vegetable grower, but its value due to the nutrients, to the organic life, and to its other effect helps to make it economically possible for the growers to purchase it. Manure reduces the acidity of acid soils and is, therefore, beneficial when lower acidity is desirable.

Manure as a Carrier of Nitrogen, Phosphorus, and Potash.—The value of manure as a carrier of these elements depends on the quantity contained and to some extent on the forms. The quantity depends on: (1) the kind of manure, (2) the quantity and kind of bedding or other material mixed with the excrement, and (3) the care the manure has had before being applied to the land.

TABLE VI.—AVERAGE COMPOSITION OF FRESH MANURES

Animal	Water, per cent	Nitrogen, per cent	Phosphoric acid, per cent	Potash, per cent
Sheep	64.0	0.83	0.23	0.67
Horse	70.0	0.58	0.28	0.53
Pig	73.0	0.45	0.19	0.60
Cow	77.0	0.44	0.16	0.40
Mixed	75.9	0.45	0.21	0.52

Analyses of manures from the various kinds of farm animals show considerable variation, but one set of figures will serve the purpose here. Table VI gives the average composition of fresh manure including both solid and liquid excrement of farm animals as reported by Hart (1912).

A ton of horse manure of average composition contains approximately 10 pounds of nitrogen, 5 pounds phosphoric acid, and 10 pounds of potash. Hen manure, analysis of which is not given in the above table, contains about 55 per cent water, 1 per cent nitrogen, 0.80 per cent phosphoric acid, and 0.40 per cent potash. From the standpoint of nutrient value hen manure ranks first and sheep manure second. Horse manure, however, is the only kind commonly available by purchase to vegetable growers. The other manures are produced mainly on farms and are used there, whereas horse manure is produced also in cities and is sold to market gardeners and others.

Manure as a Carrier and Promoter of Useful Organisms.—Manure has some value in addition to its value as a source of nitrogen, phosphoric acid, potash, and humus, although the other beneficial effects may be due indirectly to the nutrients and humus. It contains organisms which break down the organic matter of the manure itself and aids in the decomposition of the humus already in the soil. In the decomposition of the manure, materials are set free which act on some of the mineral compounds and make them more readily available to the growing plants. Manure has been found to be of value on new muck soils, even when applied in very small quantities. This could not be accounted for on the basis of the nutrients supplied, since the beneficial effect is often marked where the important elements are applied in large quantities. It is thought that the marked effect of a small quantity of manure on new muck is due to the organisms present in manure. The soil is inoculated with the organisms through it. After the initial application further applications of manure in many cases are of little or no value except for the nutrients contained. On high-lime mucks fresh, strawy manure may be beneficial for another reason, namely, preventing nitrates from accumulating in toxic quantities. Under favorable moisture and temperature conditions, nitrification goes on so rapidly in such soils that crops are sometimes injured by excess of nitrates. Coarse manure, straw, and other carbonaceous materials seem to stimulate the activity of soil organisms and these utilize nitrates. The organisms may so reduce the quantity of nitrates as to eliminate injury to crop plants. It should be borne in mind, however, that the nitrates used by the organisms are built up into more complex nitrogen compounds, which on the death of the organisms are returned to the soil. These microorganisms might, therefore, be considered as conservers of nitrogen since they utilize the nitrates, some of which might otherwise be lost through leaching.

Detrimental Effect of Fresh Manure, Straw, Etc.—Coarse manure, straw, or other similar materials sometimes have a marked depressing effect on yields of crops. It was formerly thought that the injurious effects often noticed following the application of fresh manure was due to excess of soluble nitrogen in the manure. Evidence now available indicates that the injury is due mainly, if not entirely, to a deficiency of nitrates due to their utilization by organisms which bring about the breaking down of the carbonaceous material. Laboratory studies show that such results occur when organic matter added to the soil contains a large quantity of carbon and a small quantity of nitrogen. A ratio of carbon to nitrogen greater than 15 to 1 usually results in competition with crop plants for nitrates already present in the soil. Where the soil contains little available nitrogen, or where nitrification takes place slowly, microorganisms in the manure or other humus material compete with crop plants for the available nitrates. Under some conditions this competition is serious and results in injury to the crop. One remedy for such conditions is to turn under the manure or other material far enough in advance to allow it to become at least partly decomposed before a crop is planted on the land. Another remedy is to supply more nitrates to take care of the temporary deficiency. As already mentioned, the organisms will return most of the nitrogen to the soil.

Collison and Conn (1925) call attention to another possible explanation for the injurious effects sometimes noticed following the application of straw or other carbonaceous material, namely, the presence of toxic compounds. They state that injury is often observed in the early stage of growth before nitrogen shortage could possibly have occurred. In this case, competition between the organisms and the small plants cannot account for the injury. Collison and Conn express the opinion that this early injury may be due to the presence of salicylic acid, dihydroxystearic acid, and perhaps vanillin in the straw. Chemical analyses have indicated the presence of these compounds in various plant residues. This type of injury is not likely to be found except on sandy soils containing little colloidal material. It probably would not be a factor on soils containing considerable clay, or organic matter.

Losses in Manure.—The analyses given in Table VI do not take into consideration losses incident to the ordinary handling of manure. There are three causes of losses: (1) loss of urine by drainage from the stable or yard, (2) loss of soluble material by leaching, (3) loss of nitrogen by fermentation. About 50 per cent of the fertilizing value of the excrement from farm animals is in the urine, therefore, every effort should be made to save it. The elements are present in a more readily available form in the urine than in the solid excrement. The loss of nutrients by leaching may be as much as 60 to 70 per cent in 6 months if unprotected. It is safe to say that under the usual careless manner of storing farm manures out of doors at least 50 per cent of the value of the nutrients is lost. Part of this loss, if not most of it, can be prevented by proper piling to prevent rain water from running through the pile and nutrients being lost in drainage water. The loss by leaching is due to the loss of nitrogen, phosphorus, and potassium compounds in both liquid and solid portions of the manure.

Fresh Manure versus Rotted Manure.—From the discussion of the losses incident to storing, it would seem to be the best practice to apply the manure to the land as soon as it is produced. This is not always feasible or even desirable. Very often crops are occupying all of the land so that the manure must be stored until the crops are removed. The main advantages of applying manure while it is fresh are: (1) there is little loss of valuable materials through leaching and decomposition, (2) some insoluble compounds in the soil are made soluble through the contact with the decomposing manure, (3) desirable organisms are supplied in fresh manure, and (4) heavy soils are improved by the coarse material. The possible disadvantages of fresh manure are: (1) burning effect on the plants, due to rapid decomposition of urine in manure, especially on open porous soils, (2) utilization of nitrates by the organisms in the manure, thus causing nitrogen deficiency in the soil, and (3) interfering with movement of water after being plowed under. This is especially injurious to the growing crop if the manure does not decay rapidly and acts as a mulch under the furrow slice. The injury from all of these can be obviated by plowing under far enough in advance to insure decay before the crop is planted. In addition to the disadvantages mentioned, fresh manure usually contains weed seeds and often carries spores of plant diseases. Decomposed manure contains the mineral elements in a more available form and in greater concentration than does fresh manure. The greater concentration is due to the fact that carbonaceous material has been reduced in quantity by the decomposition. The nitrogen in decomposed manure is not so readily available as that in the urine of fresh manure. The main advantages of decomposed manure are: (1) it is more even in action and carries a more evenly balanced combination of nitrogen, phosphorus, and potash than fresh manure, (2) it is not likely to cause burning, (3) the weed seeds are largely destroyed during decomposition, (4) it does not interfere with soil preparation and cultivation, and (5) it does not cause nitrogen starvation due to competition of the microorganisms and crop plants for nitrates.

Composting Manures.—Vegetable growers very often pile manure in low flat piles and allow it to decay before applying it to the land. This is often necessary since the manure is hauled when it is not practicable to apply it to the soil due to the land being occupied by crops, or for other reasons. In addition to this, well-rotted manure is preferred for many crops, due to the fact that it can be better incorporated with the soil and interferes less with planting and cultivating than coarse manure.

When manure is piled and allowed to decay before using, great care should be given to prevent leaching of the soluble materials and the loss of humus and nitrogen through fermentation. These can be prevented by stacking manure in compact, flat piles not less than 4 feet deep. With this depth there is little loss by leaching, provided the sides and ends are nearly perpendicular. By keeping the manure compact and moist, fermentation is controlled and loss of nitrogen is kept down. It is often necessary and is practically always desirable to apply water to the pile of manure to prevent excessive heating or "fire fanging." The manure should be turned two or three times at intervals during the period it is piled in order to have uniform decomposition. In turning the manure, that from the inside of the old pile should be placed on the top or sides of the new one.

Piling manure as described is often termed "composting," but in the true sense of the word a compost is a mixture of materials as manure and soil, or manure and leaves or other litter. In making a compost, fresh manure is piled in alternate layers with absorbent materials. One method of making a compost heap is to start with a few inches of loose soil or other absorbent material as a foundation and place on this a layer of fresh manure, then alternating layers of absorbent material and manure. Muck and peat are good absorbent materials and are used to a considerable extent in making compost in some of the European countries. In many parts of the United States these materials could be used to good advantage. The details of making a compost heap vary in respect to absorbent materials used, thickness of the layers, depth of the pile, etc. Sufficient absorbent material should be used to take up the soluble material and the gases from the manure. The entire surface of the pile should be covered with a layer of soil to prevent loss of ammonia.

In making a compost heap it is advisable to make use of all valuable material that is available. Trimmings from vegetables, unless seriously diseased, garbage, straw, hay that is not suitable for feed, weeds, lawn clippings, and leaves may all be added to the compost heap.

In a few weeks after the pile is completed it should be turned over and uniformly mixed and again covered with a layer of absorbent, unless it is to be used at once.

Time to Apply Manure.—The proper time to apply manure depends on the kind, the stage of its decomposition, the crops to be grown, and the rotations to be followed. When cow manure is to be applied it should be plowed under as far in advance of planting as convenient. Fall application is desirable if the land is to be plowed before winter. In the North it is not desirable to leave manure on the surface of the ground during the winter on account of loss due to leaching when the ground is frozen. Where vegetables are grown in rotation with general farm crops it is desirable to apply the manure to the vegetable crop or to the crop preceding. Well-rotted manure, especially in small applications, may be applied to best advantage after the land is plowed but before harrowing. For hen and sheep manure this is unquestionably the best practice.

Rate and Method of Application.—The rate of application of manure should be governed largely by economic considerations. The supply of manure available, the kind of crops to be grown, and the character and richness of the soil should also be considered. Heavy applications of manure cannot be justified on crops which bring a relatively low return. Where the supply is limited or the price high, light applications will usually bring the greatest net returns. With most vegetable crops 10- to 15-ton applications supplemented with chemical fertilizers will give greater net returns than heavier applications, especially if the manure must be purchased at prevailing rates. It is doubtful if more than 20 to 25 tons per acre are justified even where the price is low. It should be borne in mind that manure is not a balanced fertilizer; for this reason it is more economical to use a moderate quantity and to supplement it with chemicals.

Under most conditions broadcast application is best. The most common practice is to broadcast the manure before plowing the land. This is essential where unrotted manure is used, for unless plowed under it interferes with soil preparation and cultivation. Well-rotted manure may be applied to plowed land and mixed with the surface by harrowing. A manure spreader can be used to advantage where the quantity used justifies the investment. The spreader saves hand labor and spreads the manure more evenly than is feasible by hand.

Manure is sometimes applied in the furrow for melons and cucumbers. There is some advantage in this method where the quantity of manure is limited because it results in greater concentration in the region of the first-formed roots. Some advantage is also claimed for this method of applying fresh horse manure for the heating of the soil due to the fermentation of the material. This heat hastens the germination and early growth of melons and cucumbers. It is doubtful, however, if the furrow method of application often pays for the extra labor of applying except where only a small quantity is available. Better distribution is obtained by broadcasting.

Artificial or Synthetic Manure.—The shortage of manure has aroused interest in a process worked out in England to make artificial manure from straw or similar carbonaceous material. Hutchinson and Richards (1921), as a result of experimental work carried on at the Rothamstead Station in England, have shown that rapid decomposition of straw requires an adequate content of moisture and a suitable supply of soluble nitrogen compounds. Decomposition is hastened by the use of available phosphates and a small quantity of lime. Excess of soluble nitrogen retards decomposition and results in loss.

The straw or other material is built up into piles by layers about one foot in thickness. Each layer is wet with water and sprinkled with the mixture of fertilizer salts. The heap is built to a height of about 6 feet and is kept moist while decomposition is going on. The temperature of the heap soon begins to rise and in about 3 months the material is transformed into manure similar to barnyard manure. One ton of straw, treated with 150 pounds of fertilizer salts and sufficient water, will make about 3 tons of manure. The process has been patented and the chemicals are sold under the trade name Adco.

The making of artificial manure by the process mentioned above, or by any other method, is impracticable unless the straw or other material is available at a low price or without any cost. In other words, the vegetable grower ordinarily could not afford to buy straw for the purpose of making manure from it. There are instances, however, when a quantity of straw, refuse hay, leaves, cornstalks, or other plant material is available and might be used to advantage in making artificial manure. In such cases it might be advisable to use chemicals to hasten decomposition.

The main objections that have been raised to the English methods are the cost of the chemical treatment, the large quantity of water, and the labor required. Albrecht (1927) in Missouri and Turk (1936) in Michigan reported results of experiments that indicate that with a fairly heavy rainfall, a good grade of manure can be made from straw without supplying any additional water. In Missouri a good grade of manure was made in from 3 to 5 months and in Michigan in a period of 8 to 10 months. Where the rainfall is light during the summer, the straw requires a longer period to rot than was the case in Missouri. This is shown in the results of experiments conducted by Collison and Conn (1929) at Geneva, N. Y., and by Smith, Stevenson, and Brown (1930) in Iowa. In New York, piles made up in December contained considerable undecomposed straw at the end of a year, but when the straw was wetted artificially, it decomposed in a few months.

The rapidity of decomposition of plant residues in a compost depends on (1) the nature of the material (green or dry, young or mature), (2) the quantity of available nitrogen, phosphorus, and lime present, (3) the moisture supply, and (4) the temperature. In all of the experiments mentioned, nitrogen, phosphorus, and lime were added to the straw and other plant residues. The formula for the mixture used by Turk was as follows:

Ammonium sulfate (20 per cent nitrogen)	45 parts
Superphosphate (20 per cent P_2O_5)	15 parts
Limestone (pulverized or other forms of fine lime)	40 parts

This mixture was applied at the rate of 150 pounds per ton of dry straw. Mixtures similar to this were used by the other workers.

Manure Economy Experiments.—Several experiment stations have undertaken definite investigations looking to the solution of the problem of maintaining production of vegetables with less manure or even without it. Among the more important experiments on this problem are those reported from the Rhode Island Experiment Station by Hartwell and Crandall (1922, 1923) and by Crandall and Odland (1932); those reported from the Ohio Station by Gourley and Magruder (1924) and Comin and Bushnell (1928); and those reported from the Maryland Station by McCall and White (1924) and White and Boswell (1929). While the results of these and other experiments are somewhat conflicting, some fairly definite conclusions can be drawn from them. They have shown that, under most conditions, applications of manure above 20 or 25 tons to the acre are seldom as profitable as lighter applications, supplemented with adequate quantities of fertilizer of suitable analyses. They have shown also that production of most vegetables can be maintained without the use of manure when only one money crop is grown on the land in a year, provided sufficient fertilizer is used and the land is occupied with soil-improving crops when not in use for growing vegetables. On the other hand, in intensive gardening on mineral soil, where the land is cropped to vegetables throughout the growing season, it is difficult, if not impossible, to maintain production without the use of manure. This is due largely to the fact that the humus content of the soil is not maintained. Under this type of cropping there is not sufficient time to grow soil-improving crops in quantity large enough to maintain the soil in good condition.

Manure is not available in appreciable quantities in most of the important vegetable regions; therefore, growers are forced to grow their crops without it. On rich virgin soil crops may be produced intensively for many years without adding to the humus supply, but eventually attention must be given to supplying the soil with organic matter and nutrients.

When manure is available at low cost or is produced on the farm, there is no question as to its value. If it costs $4 or $5 a ton and must be hauled considerable distances, manure will seldom be profitable except in the most intensive type of vegetable growing where large returns per acre are obtained. In many cases, the use of manure fails to show a profit even though large increase in crop yield results from its use.

CHAPTER V

SOIL-IMPROVING CROPS

Soil-improving crops are grown for the purpose of improving conditions of the soil for the growth of succeeding crops. The terms "green-manure crops" and "cover crops" are sometimes used. Green-manure crops are those grown especially for soil improvement and turned under while they are still green, or soon after they mature. Cover crops are those which are grown for protection of the soil as well as for soil improvement through the addition of humus. They may be turned under while the plants are still green, or left until they are dead. Oats planted in the fall, or cowpeas planted in summer and left on the land all winter are illustrations of cover crops turned under as dead material.

Value of Soil-improving Crops.—Green manuring is one of the oldest methods used to maintain or to increase crop production. Green-manure crops were grown by the ancients and their beneficial effects were known long before it was understood in what ways they acted to increase crop production. Experiments have confirmed and explained the fact that green manures favorably affect succeeding crops. When a soil-improving crop is turned under, the various nutrients which have gone into the making of the crop are returned to the soil, and a quantity of organic matter is added. The organic matter improves the physical condition of the soil and serves as food for microorganisms.

Soil-improving crops increase the organic matter in the soil and this improves the texture. Heavy soils are lightened and made more porous; sandy soils are made less porous. Soil-improving crops may have the following beneficial effects: (1) to conserve soluble nutrients in the soil, (2) to add nitrogen to the soil in the case of legumes, (3) to transfer nutrients from the subsoil to the surface soil, (4) to affect favorably the growth of beneficial organisms in the soil, (5) to increase the carbon dioxide content of the soil air, (6) to improve the condition of the subsoil, (7) to render mineral nutrients available, and (8) to aid in the control of erosion. In the past a great deal was said about organic matter increasing the water-holding capacity of the soil, but results of many recent studies cast doubt on this point. It would appear, however, that a soil made friable by the addition of organic matter might absorb more water during a heavy rain than a less friable soil of the same type.

On light porous soils there may be loss of soluble salts due to leaching when the land is bare and this can be reduced or eliminated by growing soil-improving crops. These crops take up the nutrients and return them to the soil on the decomposition of the plants. For example, the nitrates in the soil are taken up and converted into complex compounds in the plant. These compounds are returned to the soil and eventually are broken down to nitrates by bacteria. Where legumes are grown, they add nitrogen to the soil through the action of bacteria which live in nodules on the roots of the plants. These plants, which have the nodule bacteria on their roots, can make use of the nitrogen of the air. The bacteria absorb the nitrogen and this can be used by the host plant, or by those which follow.

Not only do crop plants grow better in a soil well supplied with organic matter, but soil bacteria are dependent on the supply of vegetable matter for energy food. They break down the organic matter and thus make it available to higher plants.

Nitrogen is conserved by growing green-manure crops on land which might otherwise be kept bare in late summer after an early crop has been removed. Soluble nitrates in the soil are taken up by the growing manure crop and this prevents loss by drainage, or by decomposition, and the consequent escape of free nitrogen into the air. The soluble nitrates are transferred from the soil into the crop and in this form there is little danger of loss under ordinary conditions.

Leguminous crops grown as green manure add to the quantity of nitrogen in the soil owing to their ability to use atmospheric nitrogen. Green legumes may add 50 to 100 pounds and more of nitrogen per acre not including the roots and stubble. The quantity of nitrogen, of course, is dependent on the kind and the quantity of crop grown.

Organic matter affects the availability of mineral nutrients, especially phosphates in the soil. According to Hester and Shelton (1937), the humus, formed from the organic matter, unites with iron and aluminum and thus delays the fixation of applied phosphates. In addition to this the soil-improving crop takes up minerals from all parts of the soil reached by the roots and, on decomposition of the crop turned under, they are made available to the succeeding crop.

Selection of Soil-improving Crops.—In selecting crops for improving the soil the following points should be considered: (1) adaptation of the crop to the climate and soil, (2) quantity of vegetable matter produced in the time available, (3) character of root growth, (4) ease of incorporating the plant material with the soil, (5) the time the crop is to be planted, and (6) whether the crop is to be turned under while green, or as dead material.

Since in vegetable growing the organic matter is of greatest importance, under most conditions, the crop or combination of crops selected usually should be the ones that will produce the largest quantity of humus-forming material in the time available. Under most conditions of intensive culture in the North, nonlegumes, especially rye, come nearest to fulfilling the requirements. In this type of vegetable growing the obtaining of nitrogen through legumes is a secondary consideration. It is cheaper to buy nitrogen in the form of fertilizers than to get it from legumes, if the growing of legumes increases the time necessary for the production of the soil-improving crop. In other words, if rye or other nonlegume will furnish more humus in the time available than a legume crop, it usually would be preferable to grow the nonlegume and to buy the nitrogen. When the time available for growing a soil-improving crop is in summer, a crop which thrives in hot weather should be selected. For cool-season growth, as in late fall in the North and during winter in the cooler portions of the South, some hardy crop, such as rye, is desirable.

Legumes.—Where all of the conditions of weather, soil, and cropping systems are favorable, the vegetable grower would undoubtedly select one of the legumes. Such crops furnish nitrogen in addition to the humus and because of this are more valuable than nonlegumes. Among the leguminous crops grown are red clover, mammoth clover, crimson clover, bur clover, sweet clover, cowpeas, soybeans, vetch, and field peas.

Of the clovers, crimson clover is the one most commonly used as a soil-improving crop on vegetable soils since it thrives well on sandy and sandy-loam soils. This crop does not stand severe winters and so is not used much in the North. It is, however, a good catch crop since it can be grown satisfactorily between rows of vetetables. Seed of crimson clover is very often sown at the last cultivation of late vegetables. In New Jersey, Delaware, Maryland, and Virginia, and in the other states having similar climate, crimson clover does well if sown in August. In cooler regions the seed should be sown in July. Fifteen to twenty pounds of seed should be sown to the acre.

Red clover and mammoth clover are sometimes used as soil-improving crops. These clovers are used mainly in the North and the seed should be sown in July or August after the removal of early vegetables. Not less than 10 to 12 pounds of seed of red clover should be sown to the acre. The crop of red or mammoth clover may be plowed under in the fall or late in the spring.

Bur clover is one of the most valuable soil-improving crops for sections of the South, but since it is mainly a winter crop it is little used by vegetable growers. In most of the commercial vegetable growing regions of the South, vegetables are grown during the winter. Green-manure crops are produced during the summer when vegetables from the South are not in great demand.

The cowpea is the most important green-manure crop in the South, because it produces a large amount of material in a short time and thrives in nearly all sections. It requires hot weather for good growth and does not succeed well in the cooler portions of the North. This crop is grown mostly after early vegetables have been removed and before starting fall and winter crops. The varieties of cowpeas most commonly grown for manuring purposes are Whippoorwill, New Era, Iron, and Wonderful. Where root knot, caused by nematodes, is serious the Iron is probably the best variety to use since this is resistant to this disease. The usual quantity of cowpea seed sown is about 2 bushels per acre planted with a drill or sown broadcast and covered with a harrow.

The soybean thrives better on a heavier soil and in a cooler climate than the cowpea; therefore, it can be used in the North. It is grown some in the South for manuring purposes, but on poor soils it does not produce so much crop as the cowpea and the stems are coarser. The seed may be planted in rows and cultivated, or sown broadcast in the same manner as cowpeas.

Hairy vetch is grown to some extent as a soil-improving crop, or as a cover crop on sandy soils in the North. It may be sown alone, but under most conditions, it is best to sow with rye. To secure best results, seed should be sown in July or early in August at the rate of 60 to 80 pounds per acre when grown alone. It is not safe to depend on vetch alone in most instances; therefore, when it is used it is best to plant it with rye or with some other small grain crop. If the seed is not too expensive it is desirable to use some vetch with the rye when the latter is the main dependence. When sown with rye 20 to 30 pounds to the acre are sufficient.

Sweet clover is a good soil-improving crop under some conditions. There are three species and one botanical variety of sweet clover grown in the United States. Biennial white, biennial yellow, and annual yellow are the species and Hubam, an annual variety of biennial white, is the botanical variety. According to Pieters (1928) the annual yellow is useful only in the Gulf States, in the Southeast, and as far north as South Carolina, and in the irrigated sections of California and Arizona. It is an annual and, where it does well, it is a valuable green-manure and cover crop. The biennial yellow and biennial white serve the same purpose in the North. The white is preferred in most regions of the North except in western mountain states. Seed may be sown in the fall, winter, or spring, depending somewhat on the climatic conditions. When spring seeding is to be done, the seed should be sown early and it is important to use scarified seed in order to get quick germination. For fall sowing the unhulled seed is often used and this should be sown so late that germination will not take place until spring. When scarified seed is used 15 to 20 pounds should be ample, and in the drier regions 10 to 12 pounds might be better. With unscarified seed 20 to 25 pounds should be seeded. Seeding may be done with a clover drill, with a grain drill having a grass-seed attachment, or it may be broadcast by hand. When sown broadcast the seed should be covered by harrowing.

Field peas are often grown with oats or with barley. When grown with these crops the rate of seeding is one to two bushels of peas sown with the grain crop.

Blue lupine has proven to be one of the best summer legumes to use as a soil-improving crop on Long Island. It has done well on soils as acid as pH 5.0 and looks promising as a summer soil-improving crop in many regions.

Seed Inoculation.—When any of the legumes are to be grown on land that has not grown the same crop, or another crop that has the same bacteria in the nodules on the roots, the seed or the soil should be inoculated with the appropriate bacteria. The material for inoculating the seed can be purchased from commercial firms who make a specialty of legume inoculation, or from seed dealers. In some states the state agricultural college, or other public agricultural organization, furnishes inoculation material at cost.

Nonlegumes.—Of the nonlegumes rye is by far the most popular green-manure crop, because it can be grown on nearly all kinds of soils and is not adversely affected by cold weather. Rye may be planted later than other green-manure crops; therefore it is a valuable crop to use after the removal of late vegetables where, as in the North, no legume except vetch is of much value. Under most conditions in the North rye is the most valuable of all of the green crops grown for supplying humus to the soil. By planning the cropping system carefully, practically all gardeners can grow rye as a winter cover crop. When vegetable crops are harvested in late summer, too late for producing another crop, rye should be sown immediately in order to obtain a good growth before winter. This may then be turned under for early vegetables. On the other hand, if vegetables are harvested late in the fall, rye may still be sown but will not make much growth in the North until spring. In this case it is desirable to allow the rye to grow until time to plant a crop of late vegetables, such as late cabbage. It is possible, by the methods mentioned, for vegetable growers to grow rye on nearly all their land every year and still produce a money crop on the same land. To obtain a good crop of rye to turn under, at least 2 bushels of seed to the acre should be used; some gardeners use 3 bushels.

Of eleven cover crops grown in experiments on Long Island, reported by Wessels and Hartman (1937), rye was the most satisfactory. It was the only one that resulted in consistent and significant increase in yields of succeeding crops of potatoes and other vegetables.

One objection sometimes raised against rye is that it continues to grow after being turned under. Where it cannot be used for this reason oats may be substituted. The oat plant is killed by severe freezing and when sown in the fall in the North it would be turned under in the spring as dead material. Oats, or oats and peas, may be sown early in the spring and turned under in time to plant a vegetable crop in June or later.

Pearl millet is one of the best nonlegumes to use as a soil-improving crop in the summer. It grows well in hot weather and will produce a large mass of material in six weeks.

Many other nonlegumes are used to some extent as soil-improving crops. These include corn, wheat, barley, sudan grass, rye grass, timothy, sunflowers, rape, turnips, and buckwheat. For most sections, rye for a winter cover crop and corn or pearl millet for summer green-manure would meet the needs for nonlegume soil-improving crops.

The nonlegumes do not add nitrogen to the soil except as the decaying organic matter furnishes carbon as food for organisms that fix atmospheric nitrogen. They do, however, furnish organic matter and absorb nitrates and other soluble nutrients and thus tend to prevent loss by leaching during the winter.

Turning Under Soil-improving Crops.—The best time to turn under soil-improving crops depends on (1) the time the succeeding crop is to be planted, (2) the kind of soil-improving crop, (3) the season of the year when the crop is grown, (4) the condition of the soil, and (5) the climatic conditions. When the soil-improving crop is to be followed by early vegetables it must be turned under in the fall, winter, or early spring. If a late crop is to follow the soil-improving crop, the turning under should be delayed as along as is feasible in order to produce a large quantity of humus-forming material. It should be borne in mind, however, that the organisms causing the breaking down of the plant material consume nitrates and may thereby interfere with the growth of the vegetable crop as discussed in Chap. IV. The soil-improving crop may have an injurious effect on the succeeding crop due to utilization of soil moisture. A large mass of undecomposed material interferes with the upward movement of water in the soil. For these reasons it is important to turn under the material far enough in advance to allow for partial decomposition before the next crop is planted. The time required for decomposition depends on the kind of material, the stage of growth, the temperature of the soil, the soil moisture, and perhaps other factors.

In general, the more succulent the material is at the time it is turned under the more quickly it decomposes. Dry material decomposes much more slowly than green material and for this reason it is desirable to turn under soil-improving crops before they are mature, unless considerable time is to elapse between the plowing and the planting of the succeeding crop. When turning under a nonlegume sod, straw, corn stalks, or other refuse, a liberal dressing of a nitrogenous fertilizer should be given. This will tend to hasten decomposition by supplying nitrogen for the organisms and thus reduce or eliminate a shortage of it for the following crop. The recommended practice is to apply from 40 to 100 pounds of nitrogen, in the form of calcium cyanamid, nitrate of soda, sulfate of ammonia, or other carrier, to the acre at the time the soil-improving crop is turned under. The use of nitrogen in this way is especially important when material having a wide carbon-nitrogen ratio, such as mature or nearly mature rye, is turned under. When nitrogen is turned under with the organic matter, a smaller quantity of nitrogen would be used in the regular fertilizer application. The organic material turned under would make artificial manure in the soil similar to that discussed in Chap. IV.

There is a common belief that turning under a large quantity of green material will increase the acidity of the soil. While it is true that on decomposition of material of this kind organic acids are set free, the soil acidity is not increased, or if it is, the condition is temporary. Turning under humus-forming material generally does not increase the lime requirement of the soil.

Plant material decomposes most rapidly when the soil is warm and well supplied with moisture. If the soil is dry when the soil-improving crop is turned under, little or no decomposition will take place until moisture is supplied by rain or by irrigation. In regions where summer droughts are prevalent it is best to turn under the soil-improving crop while the soil is still moist, unless irrigation is practiced.

The material should be completely turned under. This is particularly important for rye and other plants that continue to grow after being plowed down, unless they are completely covered. A rolling colter on the plow beam is a great aid in turning under vine growth such as cowpeas. The colter cuts the vines and prevents their dragging. A chain or wire, with one end attached to the front end of the beam and the other to the back end so that there is a loop just in front of the mold-board of the plow, is a great help in turning under any growing material. The loop of the chain drags the tops of the plants under so that the furrow slice covers them.

CHAPTER VI

COMMERCIAL FERTILIZERS AND LIME

The term commercial fertilizer is used to distinguish between animal manures and other materials applied to the soil to furnish raw materials to the plant. When the term came into use, manure was not considered a commercial product, while the other materials used as fertilizers were so considered, hence the use of the word "commercial." A commercial fertilizer may consist of a single chemical compound, as nitrate of soda or muriate of potash, or it may consist of a mixture of several chemical compounds; or of organic materials such as bone meal, tankage, and cottonseed meal. Most mixed fertilizers contain compounds of nitrogen, phosphorus, and potash. All materials applied to the soil to furnish plants with raw material, except the animal manures and other organic wastes, are called "fertilizers" or "commercial fertilizers." Lime is a fertilizer although applied mainly to correct acidity of the soil.

Importance of Commercial Fertilizers.—In vegetable growing, commercial fertilizers are very important and are increasing in use every year. This increase is due to the shortage of animal manures and to the increasing knowledge of the value of commercial fertilizers. It is possible to grow large crops without the use of commercial fertilizers, provided manure is used in large quantity, but at the present time this is not an economical practice. Manure is not a balanced fertilizer, being especially deficient in phosphorus. If manure is applied in large enough quantities to furnish sufficient phosphorus for large yields it would result in a waste of nitrogen. Even with manure, therefore, it is usually economical to use commercial fertilizer in some form. At the present price of manure in most cities one cannot afford to use enough of it to supply the nutrients required for growing large crops.

Chemical Elements Essential to Growth.—Until comparatively recent years it was believed that only 10 elements—carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, and iron—were essential to the growth of higher green plants. It is now fairly well established that other elements are necessary for the growth of some, if not for all, green plants. Experiments have shown that manganese, boron, copper, chlorine, zinc, silicon, and sodium are needed in small quantities for some.

Merely because an element is essential to growth does not mean that it must be supplied to the soil. Most soils contain sufficient quantities of many of the elements, but a large part of the land used for vegetable production must be supplied with nitrogen, phosphorus, and potassium to produce large yields. Soils in many areas are deficient in calcium, others in magnesium, and still others in one or more of the so-called minor elements. Results of experiments have shown the desirability of supplying manganese, boron, zinc, or copper to the soil under some conditions.

Carbon, hydrogen, and oxygen are obtained from the air and from water. Some of the nitrogen also comes from the air, but most of it is obtained by plants from the soil. All of the other elements are obtained entirely from the soil. If the soil does not contain the essential elements in forms that become available to the plant, they must be supplied artificially. In practice it is found desirable to use fertilizers even though the soil contains a large potential supply of the nutrients. This is due to the fact that the elements usually are present in forms that become available too slowly for the best growth of the plants.

Commercial fertilizers are purchased mainly for their content of one or more of the three major nutrients—nitrogen, phosphorus, and potassium. It should be borne in mind, however, that other mineral elements are essential to growth of plants and that some soils are deficient in one or more of several elements. Some of these elements, such as sulphur, sodium, and chlorine, may be present in mixed fertilizer in combination with nitrogen, phosphorus, or potash. Small quantities of some of the so-called minor elements may be present as impurities in commercial fertilizers, but the tendency in fertilizer manufacture is to increase concentration and purification of the nitrogen, phosphorus, and potassium compounds.

During recent years many physiological disorders have been shown by experiment to result from a deficiency of one or more of the essential elements. These troubles appear to be increasing in importance, and it seems safe to assume that such disorders will become more and more prevalent as time goes on unless the deficient elements are supplied to the soil. The deficiency troubles result mostly from a deficiency of some of the so-called minor or trace elements. Many factors have contributed to the deficiency of minor elements in the soil. Some of these factors are:

1. Intensive production of crops and continued drain on the supply of the mineral elements in the soil by removal in the harvested crop.
2. Loss by leaching.
3. Decrease in the use of manure in vegetable production. Manure contains all of the mineral elements that are in the food consumed by the animals and when manure is used in considerable quantities minor-element deficiency is seldom encountered.
4. Increase in purity and concentration of the common fertilizer chemicals. Until recent times a considerable portion of the ingredients used as fertilizers carried

appreciable quantities of many elements in addition to nitrogen phosphorus and potash. The ingredients included organic materials of plant and animal origin and natural deposits of nitrates, phosphates, and potash salts. The increasing use of synthetic nitrogen compounds and the increasing purification of the compounds of phosphorus and potash used as fertilizers have resulted in decreasing the content of other elements that were formerly present as so-called impurities.

Quick Tests for Determining Fertilizer Needs.—For a number of years there has been great interest in quick chemical tests of soils to determine fertilizer needs and many tests have been devised. In some cases the tests have been commercialized. These rapid tests are used by many experiment stations and agricultural colleges as an aid in giving advice to farmers regarding use of fertilizer. According to Thomas (1936), 26 states, principally in the central-western area, corn belt section, and eastern Atlantic region, make extensive use of these tests for evaluating fertilizer requirements and 17 other states make limited use of them. The fact that these tests are used by so many experiment stations and agricultural colleges is fairly good evidence that they have value as an aid in diagnosing soil needs, when interpreted by trained men. The writer believes that they can be used to advantage as an aid in determining the possible cause of unproductiveness of a soil. They should not be expected to give the necessary information for determining the exact fertilizer requirement of any crop on a particular soil. No form of soil analysis will supply this information.

The methods of making the tests vary considerably in respect to acidity and other characteristics of the extracting solution. Some extracting solutions consist only of an acid and others consist of acids well buffered with salts. The ratio of soil to extracting solution and the time of contact vary also in the different procedures. As might be expected the different procedures do not give the same results even when used on the same soil, as was shown by Anderson and Noble (1937) in their comparison of a few of the methods. Schreiner and Anderson (1937) described the various methods of determining the fertilizer requirements and listed the principal quick-test methods that are in use.

Several investigators including Emmert (1930, 1932, and 1934), Thornton (1932 and 1933), Thornton, Connor, and Fraser (1934), and Carolus (1938) have described plant tests for determining fertilizer needs. These tests seem to be well adapted to the determination of nutrient deficiencies. It would seem that tests made on both soil and plants would be more reliable than tests of either alone.

While these soil and plant tests undoubtedly are of value in the hands of trained, experienced persons, they might be worthless or entirely misleading in the hands of amateurs. Experienced workers would not base their diagnoses or recommendations entirely on the results of the quick tests, but would take into consideration information from many other sources.

Value and Use of Nitrogen.—Of the three elements commonly supplied by commercial fertilizers, nitrogen has the quickest and most pronounced effect. It is a constituent of all proteins, which are probably the active components of protoplasm. It tends to encourage the development of the vegetative, above-ground portion of the plant and to impart a deep green color to the leaves. It increases plumpness in seeds and it governs, to some extent, the utilization of potash and phosphoric acid. Nitrogen tends to produce succulence, a quality of great importance in many vegetables. Of the three elements commonly used, nitrogen is more likely to be the limiting factor than either potash or phosphorus because it is lost from cultivated soils more quickly, and also because it is more expensive, and therefore, less likely to be supplied in sufficient quantities.

Many different carriers of nitrogen are now used as commercial fertilizer. Some of these, as cottonseed meal, linseed meal, and castor bean meal, are of plant origin, others as blood meal, meat meal, tankage, and fish tankage are of animal origin, while still others are synthetic in origin or occur as natural deposits. Of the synthetic nitrogenous materials cyanamid, calcium nitrate, urea, and ammonium nitrate are examples. Ammonium sulphate is a by-product of coke ovens and city gas plants. Nitrate of soda is mined from deposits in South America, especially in Chili, but is also being made synthetically in the United States and in Europe. Nitrate of potash occurs in small deposits in various parts of the world, but it may be made from nitric acid and potassium hydroxide.

Value and Use of Phosphorus.—Many soils are poor in readily available phosphorus although there may be considerable quantities of phosphorus compounds in the soil. For growing vegetables on practically all soils, it usually is desirable to apply fertilizers containing this element. Phosphorus is a constituent of nucleoproteins and lecithins. It is thought to be important in enzyme action. Phosphorus is supposed to hasten the maturity of the plant, increase root development, especially the fibrous roots, improve the quality of the crop, and increase resistance to disease. Phosphorus is thought by many to counteract the effects of overstimulation due to excess of nitrogen.

The chief sources of phosphorus used as fertilizers are phosphate rock and animal bones. The former is much the more important at the present time. The rock contains phosphorus in the form of tricalcium phosphate, which is treated with sulphuric acid to form superphosphate, the material commonly used by vegetable growers. The phosphorus in superphosphate is available to the plant. Most of the bone fertilizer now on the market is first boiled or steamed to free it from fat and nitrogenous material. Steamed bone is more valuable than raw bone as a fertilizer, because the fat in the latter retards decomposition. The phosphorus in both raw and steamed bone is in the form of tricalcium phosphate, which is not readily available to the plant, and therefore, should not be used as a source of phosphorus for immediate results. The bone may, however, be treated with sulphuric acid and the phosphorus changed to the available form.

Value and Use of Potash.—Potash is essential to growth of plants. It is supposed to be essential to the formation and the translocation of carbohydrates, and is used in large quantities in the production of root crops. Deficiency of potash results in abnormal leaf color and weak stems. Potash may be present in large quantities in the soil without exerting a harmful effect on the crop. It should be generally used in mixed fertilizers for vegetable growing. Applications of potash are particularly important for sandy soils and muck soil, the latter being practically always poor in this element.

The main potash compounds used as fertilizers are muriate and sulphate of potash, but kainite, manure salts, and wood ashes are also used. Muriate is the most common form used by vegetable growers, but sulphate is preferred by some and kainite is favored by some asparagus growers. Some of the preference for sulphate over muriate is not borne out by experimental data. For most crops the muriate is at least equal to the sulphate and is cheaper.

Value and Use of Calcium.—While it is often stated that lime is not a fertilizer, but rather a soil amendment, it should be borne in mind that calcium, the important element in lime, is essential to the growth of all of the higher plants. This fact has been known by plant physiologists and other students of plant science for a long time, but it is only within recent years that its importance as a constituent of the cell wall has been realized. True (1922) pointed out that unless sufficient calcium ions are present in the culture medium to unite with the pectic acid to form the calcium-pectate middle lamella the cells may disintegrate. In solutions containing potassium and insufficient calcium the potassium ions unite with pectic acid to form potassium pectate which is relatively soluble, and the cells fall apart. Calcium ions actually diffuse out into the solution. With magnesium solutions the pectic acid unites with the magnesium ions to form magnesium pectate which apparently becomes toxic. When all of the calcium is replaced by magnesium the cells die. Death is probably due to the toxic action of the magnesium ions on some of the cell structures.

Many soils contain sufficient calcium to meet the needs of crop plants from the standpoint of its use in the cell wall. In most mixed fertilizers and in superphosphate, calcium is present combined with phosphorus, and it is probable that where these fertilizers are used this would meet the needs as far as nutrition of the plant is concerned. In other words, it is doubtful if a special application of a carrier of calcium is often necessary or even desirable except when lime is needed to correct soil acidity.

Value and Use of Sulphur.—Sulphur is essential to the formation of most proteins and cannot be replaced by any other element. This fact has been known for a long time, but until recent times it has been assumed that all soils contained sufficient sulphur to meet the needs of crop plants. However, the plant uses much more sulphur than was formerly supposed, since the methods of analysis formerly used took into consideration only the sulphur that appeared in the ash as sulphates. Improved methods of analysis show that the total sulphur present in many plants nearly equals the quantity of phosphorus in the same tissue. Recent experiments have shown that part of the beneficial effects of many fertilizers is due to the presence of sulphur in the form of sulphates. While it is true that under most conditions sufficient sulphur is present in the soil and supplied in fertilizers to meet the needs of most crops, there is some evidence that it may be desirable to apply this element.

Sulphur increases soil acidity and has been used to some extent to control potato scab. It should be used with caution and only where it is definitely known that higher acidity is desirable.

Value and Use of Magnesium.—Magnesium is a constituent of the chlorophyll molecule, serving as a means of linkage between its component organic groups. When magnesium is absent from the culture medium the plants are etiolated and chlorotic. Magnesium seems to be necessary for fat formation, but it has been suggested that the large quantity of this element in oily seeds may be related to phosphorus translocation rather than to fat formation.

Magnesium deficiency has been reported in many sections of the United States, especially along the Atlantic coast from Maine to Florida. Drainage waters in the Atlantic coast region contain only from 1 to 3 parts per million of magnesia (MgO) as compared with over 20 parts per million in Illinois, Iowa, Minnesota, North Dakota, South Dakota, and portions of the Southwest. Sandy, well-drained soils are most likely to be deficient in magnesium.

Results of experiments in several areas in the Atlantic coast states have shown the importance of applying magnesium to the soil in some regions. Carolus and Brown (1935) have reported results of experiments conducted on light soils in the eastern part of Virginia in which application of magnesium increased the yields of many vegetable crops. Some of the increases in yield were very large—from about 10 per cent to as high as 194 per cent. The authors state that magnesium influenced earliness, uniformity of maturity, and the general quality of the marketable portion of the crops grown.

Magnesium deficiency can be remedied by the application of high-grade dolomitic limestone to maintain the soil at the optimum reaction for the crops that are grown. Carolus and Brown suggest that this liming practice be followed until a total of 500 to 750 pounds to the acre of magnesia (MgO) has been added to the soil. After this reserve has been built up, it can be maintained by applying sufficient dolomitic limestone to replace the quantity of magnesium removed through leaching and through removal by the crop. If the lime is not needed to correct acidity, soluble magnesium salts may be added to the fertilizers used.

Excess of soluble magnesium salts in the soil produces toxic effects on plants. Calcium is very efficient in counteracting the harmful effects of magnesium salts and it is because of this fact that so much attention has been given to study of the calcium-magnesium ratio in plants.

Value and Use of Sodium.—Sodium has not been considered as essential to growth although it is present in small quantities in the ash from practically all plants. It is known that sodium can liberate some of the other elements, and may therefore be of some indirect value when applied to the soil. Experiments have shown that in cases of insufficient potassium, sodium can perform a part of the role of that element.

Working (1924) found that young asparagus seedlings gave a better yield in solution culture when the solution contained sodium in concentrations less than 0.5 molar, than in others which did not contain this element.

Value and Use of Chlorine.—Chlorine is found in small quantities in plants, and it is thought that it is essential to the growth of some. Some authorities believe that common salt is of value in growing asparagus due to chlorine rather than to the sodium. This belief is based on observation and some experimental evidence that muriate of potash gives better results than sulphate of potash, and that common salt does not increase the yield when applied with the former, but does increase it when applied with the latter. The evidence on this subject is not sufficient to justify positive statements, and the results obtained by Working casts considerable doubt on the belief of the possible value of chlorine in growing asparagus.

Value and Use of Manganese.—Manganese appears to be essential to chlorophyll formation although it is not a part of the chlorophyll molecule. The first sign of the lack of this element is the failure of the plant to synthesize chlorophyll and it is thought that it may act as a catalyzer, especially in oxidations.

Deficiency of available manganese has been shown in many soils, especially those that are nearly neutral, neutral, or alkaline in reaction.

Results of experiments conducted in many regions have shown the importance of applying a manganese salt to certain soils. Skinner and Ruprecht (1930) found that on calcareous glade soils in Florida crop yields were increased considerably by manganese salts. Manganese sulphate applied at the rate of 50 to 100 pounds to the acre gave satisfactory results on these soils with several kinds of vegetables. Townsend and Wedgeworth (1936) showed the need for manganese on slightly acid or alkaline peat soils of the Florida Everglades. They obtained large increase in the yield of snap beans from manganese alone or with manganese and sulphur. The sulphur increased the acidity of the soil and thus increased the availability of the manganese.

Soluble manganese salts may be applied to the soil or mixed with the fertilizer or they may be applied as a spray to the foliage. Townsend and Wedgeworth found that two applications of a solution of four pounds of manganese sulphate in 50 gallons of water usually were sufficient for beans.

Value and Use of Zinc.—While the writer knows of no experimental results in which the use of zinc has had any appreciable effect on yield of vegetable crops, many experiments have shown that this element controls certain malnutrition diseases of other plants. Certain disorders of deciduous fruits, citrus fruits, pecans, and tung-oil trees have been reduced or controlled completely by the use of zinc. Barnette, Camp, Warner, and Gall (1936) reported a chlorosis of corn that is controlled by a small application of zinc sulphate. This chlorosis, which develops when corn is grown on certain soils in Florida, begins to appear within a week or two after the seedlings emerge. Light yellow streaks appear between the veins, and small white spots develop rapidly in the leaves. The unfolding buds have leaves that are white to light yellow and this characteristic has given rise to the use of the term "white bud." In advanced stages the older leaves become bronze to gray in color. It seems probable that sweet corn would be affected by the same disorder if grown under the same conditions. Barnette *et al.* have shown that the yield of several other crops was increased by the application of zinc sulphate even though no deficiency symptoms were in evidence. It might be expected that some of the vegetable crops would respond to zinc when grown on soils that are deficient in this element.

Value and Use of Copper.—Copper has been used as a fungicide for a long time, but it is only relatively recently that it has been found of value as a nutrient. One of the most striking examples of stimulation of plant growth by the use of copper is that reported by Allison, Bryan, and Hunter (1927) in connection with experiments on the peat soils of the Florida Everglades. On certain areas most of the agricultural crop plants failed to grow satisfactorily and in experiments with a number of mineral elements it was found that response was greatest from copper. Applications of from 30 to 50 pounds of copper sulphate to the acre was recommended by Allison *et al.*

Felix (1927) called attention to areas of muck soil in western New York that produced poor crops, especially of lettuce and onions. He found that the most prevalent type of unproductiveness could be corrected by the addition of from 100 to 200 pounds of copper sulphate to the acre. Dusting lettuce plants with 20–80 copper-lime dust at the rate of 55 pounds to the acre resulted in normal growth.

Many areas of muck soils in New York produce onions of poor color and with thin scales. Such onions bruise easily and do not keep well in storage. Results of experiments by Knott (1933) with several mineral elements showed that this trouble could be eliminated by applying copper sulphate. He recommends from 200 to 300 pounds of powdered copper sulphate to the acre. One application is sufficient for several years and need not be repeated until the onions begin to show poor color.

Value and Use of Boron.—It has been known for many years that boron is essential to growth of some plants, but only within recent years has boron deficiency been recognized in cultivated soils. Investigators in Europe, in Canada, and in the United States have shown that certain physiological diseases can be controlled by a small application of borax or boric acid. Experimental results have shown that heart rot or crown rot of sugar beets; brown heart (black heart, dark center) of swedes or rutabagas; cracked stem of celery; and brown rot, red rot, or browning of cauliflower are controlled by suitable applications of boron in the form of borax, or boric acid. Recently Raleigh and Raymond (1937) have reported results of preliminary experiments on the use of boron in controlling an internal breakdown in table beets. The use of boron for the control of the specific troubles mentioned is discussed in the appropriate crop chapters.

Boron is highly toxic to plants and, for this reason, it must be used with great care and in no larger quantity than is necessary to control the trouble for which it is employed.

Value and Use of Iron.—Iron seems to be essential to chlorophyll formation although it is not a constituent of the chlorophyll molecule. When iron is absent from the culture medium the plant does not produce chlorophyll. It is not known how iron is related to chlorophyll formation, but some authorities have suggested that it acts as a catalytic agent.

Iron is used in small quantities by plants and most agricultural soils contain enough for crop production. There are, however, conditions under which soluble compounds of iron must be used in order to obtain good growth. Soluble ferric compounds are the source of supply of iron; ferrous compounds are highly toxic.

Fertilizer Analysis.—The *analysis* is the statement of the percentage of nitrogen, phosphoric acid, and potash contained in a complete fertilizer, or of one of these nutrients in a separate material. In most states a statement of the analysis is required by law. This statement is printed on a tag, or on the bag. Some manufacturers give a "guaranteed analysis," which is a warranty that the fertilizer contains the percentage of nutrients shown in the printed analysis. The analysis is often represented by three figures, as 5–10–5, 3–12–18, or 10–20–10. These figures represent the analysis of a complete fertilizer, the first giving the percentage of nitrogen, the second the available phosphoric acid, and the third the percentage of water-soluble potash.

During recent years marked changes have taken place in the concentration of fertilizers. In many states a mixed fertilizer containing less than 20 units of nutrients is termed a low-analysis fertilizer and is not recommended. No complete fertilizer containing less than 20 units is considered a high-analysis fertilizer and such analyses as 8–16–8, and 10–20–10 are being used in increasing quantities each year. The fertilizer industry and the agricultural workers in many states are cooperating in a program to eliminate low-analysis fertilizers because such analyses are uneconomical for the farmer. The use of the terms low analysis and high analysis has resulted in some confusion since some users have assumed that the value of a fertilizer depended on the total number of units regardless of the proportion of nitrogen, phosphoric acid, and potash. This is not correct. Nitrogen costs much more per pound than either phosphoric acid or potash. Two mixtures may have the same number of total units, but differ markedly in price because of the difference in the proportion of the three important constituents. For example, 2–8–10 and 5–10–5 analyses contain 20 units of nutrients each, but the latter costs considerably more and is worth more on most upland soils.

The buyer of fertilizer should make his purchase on the basis of the analysis and formula rather than on the price. A ton of 10–20–10 fertilizer contains exactly twice the quantity of each of the three important nutrients as a 5–10–5; therefore, the former is worth twice as much per ton as the latter, if the materials used are of equal quality. A ton of 10–20–10 should cost less than two tons of 5–10–5 since many of the cost items, such as bags, freight, handling, etc., are essentially the same per ton for the two fertilizers. In general, the nutrients cost less per pound when purchased in a high-analysis and in a concentrated fertilizer than in a low-analysis one.

Fertilizer Formula.—The "formula" is the statement of the kinds of materials and the quantity of each used in making a ton of mixed fertilizer. While the fertilizer industry has not chosen to state the materials used in mixed fertilizers, there is a trend toward what is known as "open formula" fertilizers. Users of fertilizers have a right to know the materials used, and are coming more and more to demand this information. It is particularly important to know the source of nitrogen, since in some carriers it is in a readily available form, while in others it is slowly available. The nitrogen compounds in some of the organic carriers, such as cottonseed meal, castor meal. tankage, and others, must undergo nitrification before the nitrogen is available and this process is slow when the soil is cold.

Another important consideration in the fertilizer formula is the effect of the material on soil reaction. Some materials, such as sulphate of ammonia, leuna saltpeter, leunaphos, leunaphoska, and acidulated fish, tend to increase soil acidity. Others, as nitrate of soda, calcium nitrate, rock phosphate, bone meal, and basic slag, tend to decrease acidity, while still others have little or no marked effect on soil reaction. The change in soil reaction following applications of fertilizer is usually due to the residue left after plants have taken the important nutrients. For example, in nitrate of soda, the nitrate is used and the sodium is left and since this is a base it unites with acids in the soil, thus decreasing the acidity. Where sulphate of ammonia is applied the ammonia is used by the plant and the sulphate ion, which is acidic, is left in the soil.

Many vegetable growers prefer to have the nitrogen in mixed fertilizers in two different carriers: one in which the nitrogen is readily available, and the other in which it is slowly available. For this reason, and also because of the need of a drier, the animal and vegetable materials have been in demand. Since many of the nitrogenous materials of animal and plant origin are also used as feed for livestock, the nitrogen costs more from these sources than that from other sources. In fact, the higher grades of animal and plant carriers of nitrogen are too expensive to use as fertilizers and are being replaced by lower grades of materials of this nature, and by nitrogen salts of various kinds. The only real need for animal and plant materials in fertilizers is for their physical effect. They act as driers and thus prevent caking and insure reasonably good drilling. Some fertilizer manufacturers are making a granular or pelleted form of fertilizer which drills well and does not cake on standing. In some cases the individual ingredients are granulated separately and then mixed, while in other cases the mixture is made and then put in the form of granules or pellets. In the latter case each granule or pellet contains the complete mixture. One advantage claimed for the granular material is that the compounds are not so readily fixed in the soil as is the case with the materials in powdered form.

Fertilizer Ratio.—The *fertilizer ratio* is the proportion of the three principal nutrients in a mixed fertilizer, or the quantitative relation they bear to each other. The term fertilizer ratio has come into use because of the large number of possible analyses with the same proportion of nutrients. It is much simpler to base fertilizer practice on a fertilizer ratio than on an analysis. For example, if it is desired to use a fertilizer containing twice as much phosphoric acid as nitrogen and potash, a large number of analyses are possible, such as 4–8–4, 5–10–5, 6–12–6, 7–14–7, and so on up to 15–30–15. All of these analyses have the nutrients in the ratio 1–2–1. Only a few ratios are necessary such as 0–2–1, 1–1–1, 1–2–1, 1–3–1, 1–4–1, 0–2–3 and 1–2–3.

The fertilizer ratio that should be selected depends to a considerable extent on the rate of application and on the crop to be grown. In general, where heavy applications are used in intensive gardening on sandy-loam soils, a ratio approaching a 1–1–1 is desirable. For example, where it has been the practice to use a ton or more of 5–10–5 to the acre, experimental evidence indicates that a fertilizer having equal quantities of the three important constituents would be more nearly correct. On heavier soils, such as silt loams, loams, and clay loams, where the applications have been at the rate of 1,000 to 1,500 pounds to the acre of a good mixture, a 1–1½–1, or 1–2–1 ratio would probably be better than the 1–1–1, because phosphorus is more likely to be needed in greater quantities than are the other elements. When vegetables, such as cabbage, potatoes, and others (tomatoes, peas, and sweet corn for canning), are grown in rotation with general farm crops and where manure is used in the rotation, a 1–3–1, or 1–4–1 ratio probably should be selected. Under such conditions the rate of application usually is relatively small, often being only 300 to 400 pounds of a 4–12–4 or 4–16–4, and seldom exceeds 800 to 1,000 pounds to the acre of such analyses. Under good farming practice in some regions only superphosphate is used on the vegetable crops grown in rotation with farm crops. Where considerable manure is used or where the soil is rich, this practice probably is sound.

For vegetables grown on muck soils the fertilizer used is high in potash, since most mucks are low in this element. Fertilizer ratios for these soils include 0–2–3, 1–2–3, and 1–4–6. The ratios and quantities recommended for the various crops under different conditions will be found under the discussion of the crops in Chaps. XVI to XXVII.

Home Mixing of Fertilizers.—While most fertilizer users prefer to buy factory-mixed goods, a small percentage like to do their own mixing. The main advantages of home mixing are: (1) better knowledge of the materials used, (2) better opportunity to have mixtures to fit the needs of the several crops, and (3) lower cost. Most manufacturers of mixed fertilizers do not give information as to the materials used in compounding the mixture and this is an important thing for the user to know. When he buys and mixes his own goods he has this information. In home mixing it is feasible and practicable to mix the ingredients to get any ratio of nitrogen, phosphorus, and potash that is desired.

The main disadvantages of home mixing are the difficulty of getting a good, uniform mixture with the facilities usually available on the farm, and the difficulty of getting the separate ingredients in many localities. Where only a few tons of fertilizer are used it is doubtful if home mixing would pay for the trouble. When the mixing is done by machinery the material is usually in better condition for distribution than when it is done by hand.

Certain materials should not be mixed since they have a deleterious effect on others. Lime in any form and basic slag should not be mixed with superphosphate since the lime reduces the percentage of readily-available phosphoric acid. The lime-carrying materials should not be mixed with sulphate of ammonia or other ammonium salts since lime may cause loss of ammonia.

Where fertilizer is to be mixed some considerable time in advance of applying it to the land, some drier or conditioner is needed to keep the mixture in good condition for drilling. Many materials, such as nitrate of soda, calcium nitrate, and other nitrates, as well as kainite and manure salts, take up moisture from the air and the drier is needed to prevent lumping of mixtures containing any of these. The materials commonly used as driers are the organic nitrogen carriers, as dried blood, tankage, cottonseed meal, castor meal, garbage, dried ground fish, and linseed meal. Usually 300 to 400 pounds of a good drier to the ton is sufficient to keep the mixture in good condition. When the fertilizer is to be applied immediately after mixing no drier is necessary, and leaving it out results in some savings in the cost of the nitrogen.

The selection of materials for home mixing should be based on the cost of the nitrogen, phosphoric acid, and the potash in the various carriers, on the availability of the nitrogen, and on the effects the materials have on soil reaction. Principles discussed under "Fertilizer Formula" (page 61) should govern the selection of materials for home mixing.

The calculation of the quantity of materials necessary to make up a ton of fertilizer of a given analysis is a matter of simple arithmetic. The analysis, as 5–10–5, means the per cent, or the pounds in 100 of nitrogen, phosphoric acid, and potash in the complete fertilizer. Since a ton is 20 hundreds, multiplying each figure by 20 gives the pounds of each of the three nutrients in a ton of 5–10–5 fertilizer, *viz.*, 5 × 20 or 100 pounds each of nitrogen and potash and 10 × 20 or 200 pounds of phosphoric acid. It is necessary to know the composition of the materials used in making the mixture and this is usually given on the bag or on a tag. The next step is to find the quantity of each material to use to supply the total quantity of nitrogen, phosphoric acid, and potash in a ton of 5–10–5 fertilizer. To determine the quantity of each material, where only one source of an element is to be used, divide the total quantity of nitrogen, phosphoric acid, or potash by the per cent composition of each material and multiply by 100. For example, to find out how much nitrate of soda is necessary to supply 100 pounds of nitrogen, divide 100 (the pounds of nitrogen required) by 15 (the percentage of nitrogen in nitrate of soda) and multiply by 100; thus, $\frac{100 \times 100}{15} = 666$ pounds. For supplying 200 pounds of phosphoric acid in 20 per cent superphosphate the calculation would be $\frac{200 \times 100}{20} = 1{,}000$ pounds. Likewise for potash, using muriate, $\frac{100 \times 100}{60} = 166$ pounds of muriate of potash. Where more than one material is used to supply a given nutrient, it would be necessary to decide on the quantity of one material and then make the calculation for the other as given above. Suppose, for example, 200 pounds of nitrate of soda is desired. This would supply 30 pounds of nitrogen. If the remainder was to be supplied as sulphate of ammonia the calculation would be $\frac{70 \times 100}{20} = 350$ pounds. If one wanted to make a 5–10–5 mixture using nitrate of soda, sulphate of ammonia, 20 per cent superphosphate, and 60 per cent muriate of potash the formula might be as follows:

	Pounds
Nitrate of soda (15 per cent N)	200
Sulphate of ammonia (20 per cent N)	350
Superphosphate (20 per cent P_2O_5)	1,000
Muriate of potash (60 per cent K_2O)	166
Total	1,716

This is not a ton but contains exactly the same quantity of each of the three important nutrients as a ton of 5–10–5 fertilizer and the farmer would have 1716 pounds instead of a ton. If one desires some organic source of nitrogen and a drier as well, he might make up a mixture according to the following formula:

	Pounds
Tankage (5 per cent N)	300
Nitrate of soda	100
Sulphate of ammonia	350
Superphosphate (20 per cent P_2O_5)	1,000
Muriate of potash (60 per cent K_2O)	166
Total	1,916

This 1916 pounds contains the same quantity of nitrogen, phosphoric acid, and potash as a ton of 5–10–5. In a fertilizer mixing plant a filler of inert material would be used to make the weight up to a ton if the materials and proportions specified were used. A low-grade organic material might be used to increase the weight and supply part of the nitrogen, thus reducing the quantity of filler used or eliminating the filler altogether. The formulae given are for purpose of illustration rather than as recommendations.

In mixing fertilizers it is important to have the ingredients well mixed. A smooth, tight floor, a set of scales, shovels, hoes or rakes, and a wire screen of about ½-inch mesh, are needed. It is convenient to mix a ton at a time and a common procedure is to pour out about half of the superphosphate in the center of the floor, level with a hoe or a rake, then add about half of each of the other ingredients, leveling after each is poured on the pile. Now add the remainder of the superphosphate and of each of the others in the same order as before. Then begin at one end and turn the pile in one direction. Set up the screen at an angle of 35 to 40 degrees and shovel the material on it. The fine material will go through and the lumps will roll to the bottom where they can be crushed with the back of the shovel or with a lump crusher. After being screened, the pile should be turned again to be sure of getting the materials well mixed. Where mixing is to be done on a large scale it is advisable to have mechanical mixers. This is seldom practicable for individuals, but cooperative buying organizations often find power-driven mixing machines a good investment.

Time and Method of Application.—Fertilizers for vegetable crops commonly are applied before, or at the time of, planting. It is considered best to apply the fertilizer a few days prior to planting, under most conditions. Where applications are made with a fertilizer attachment of the machine, as with corn and potato planters, the most practicable time to apply the fertilizer is at the time of planting the seed. Under most conditions there is no advantage in making more than one application, except where a soluble carrier of nitrogen is applied broadcast or as a side dressing. Experiments have shown as good or better results from a single application as from two or more when the same quantity of material is used. It costs more to make two applications than to make one; therefore, one is commonly recommended.

Considerable experimental work has been done in recent years to determine the best methods of applying fertilizers to various crops and under different conditions. As early as 1925 Truog *et al.* (1925) published results of experiments which showed that a small quantity of fertilizer applied in the hill or row produced as large yields as much larger quantities applied broadcast, provided the material was not placed near enough to the seed or plants to cause injury. Results of more recent experiments have been reported by Cummings *et al.* (1936) on snap beans in Florida, by Sayre and Cummings (1936) on cannery peas in New York, and by several others on various crops in many regions. A report of the National Joint Committee on Fertilizer Application published by the National Fertilizer Association in 1937 gives a brief summary of fertilizer placement studies on beans, cabbage, cauliflower, celery, collards, kale, lettuce, onions, potatoes, spinach, sweet potatoes, and tomatoes. Results of most of these studies indicate that placement in bands 2 to 4 inches to the side of the row and level with or below the seed, or roots of transplanted plants, is better than placement under the seed, over the seed, or broadcast. Pea and bean seedlings are seriously injured by contact with the fertilizer even when only a small application is made. Sayre and Cummings showed reduction in germination of pea seed when 150 pounds of 4–16–4 fertilizer was applied with the seed, and still greater reduction from 300 pounds of this fertilizer applied in the same way. Similar results have been obtained with beans. Cummings *et al.* got no germination of bean seed where 700 pounds of 5–7–5 fertilizer was applied in contact with the seed.

Placement of fertilizer in bands near the row seems to be especially desirable when only a small application is used, but with most crops it is not safe to have the fertilizer come in direct contact with the seed. Several explanations have been offered for the superiority of band over broadcast application. One is that the fertilizer is placed near the row where the plant will reach it in the early stage of growth. Another explanation is based on the fixing power of the soil for phosphorus. Some soils have a high fixing power for phosphorus and when the fertilizer containing phosphates is applied broadcast most or all of the phosphorus may be fixed and thus rendered unavailable to the plant. When the fertilizer is applied in a narrow band, it is in contact with a small quantity of soil; therefore, not much of the phosphates would become fixed.

For most crops it is safest and best to apply the fertilizer either in bands or broadcast, especially where considerable quantity is used. While results of some experiments seem to indicate that a small quantity applied near the row produces as large yields as twice the quantity applied broadcast, it would not be safe to recommend cutting the application in half when band placement is followed. Most fertilizer placement studies have not been carried on long enough on the same land to justify such recommendations.

Various drills and fertilizer distributors have been placed on the market and they all are of value. There are drills to apply the fertilizer in the row, others to distribute it in a strip along the row, and still others to scatter the fertilizer in a strip 8 to 10 feet wide. The last-mentioned type is used for applying fertilizer to the whole area to be planted, the application being made before the land is harrowed. The grain drill is often used since it usually has a fertilizer attachment. Lime spreaders can also be used for applying fertilizers. All of these drills and distributors can be set to apply fertilizer at almost any rate desired.

Where the fertilizer is applied broadcast on the surface of the soil it should be thoroughly mixed with the surface few inches by harrowing. A common practice is to sow the fertilizer on the land after plowing, but before harrowing. This is a good practice, but the use of a drill, which places the material below the surface, is also a satisfactory practice and has the advantage of preventing loss by wind blowing the fertilizer away.

Rate of Application.—Obviously the rate of application of fertilizers should be considered only in connection with definite analyses, but there is great confusion in the discussions one hears on this point. It is not uncommon to hear discussions of rates of applications without mention of analyses, or of analyses with no reference to rates of application. With the large number of analyses now available and with what seems to be a necessity to consider ratios, there is need for a change in the terminology. Instead of discussing applications in terms of hundreds of pounds of a mixture per acre, we should discuss them in pounds of nitrogen, phosphoric acid, and potash to the acre. For example, we might recommend 100 pounds of nitrogen, 200 pounds of phosphoric acid, and 100 pounds of potash to the acre. An application of one ton of 5–10–5 would supply these quantities. If one used a 10–20–10 only a half ton would be required, and should he choose to use a 15–30–15 analysis, only a third of a ton would be needed. Similarly with the other ratios, thinking in terms of the nutrients rather than in terms of the total number of pounds of the mixture to use would simplify matters and avoid confusion. We might recommend 500 pounds of a 4–16–4 fertilizer per acre for a given crop, but a 5–20–5 or 6–24–6 might be a better buy. If instead of suggesting the 500 pounds of 4–16–4 one recommended 20 pounds of nitrogen, 80 pounds of phosphoric acid, and 20 pounds of potash, the prospective user is more likely to think in terms of the things he is actually buying, namely, nitrogen, phosphoric acid, and potash.

The rates of applications of the important nutrients should be based on the fertility of the soil, the cropping system, the crop to be grown, and the gross returns that reasonably might be expected from the crop. Where the land is well supplied with one of the elements in forms available to the crop, obviously it would be poor economy to use much of that element in the fertilizer mixture. On many muck soils it is a waste to use much nitrogen since such soils are rich in this element. On soils containing considerable clay little potash is needed.

Rates of applications of ordinary mixed fertilizers, such as 5–10–5, 5–8–7, 4–12–4, vary from a few hundred pounds to the acre to a ton or more per acre. Some growers use as much as 2 tons and even more of a 5–10–5 or similar analysis per acre but it is doubtful if more than one ton is justified for most vegetables. Certainly large applications are never justified unless the soil is in good mechanical condition. There is considerable evidence that large applications of commercial fertilizers are harmful, especially where there is a deficiency of humus in the soil. Some so-called malnutrition diseases have been traced to large applications of fertilizers.

Where the gross returns from the crop are low, it is economically unsound to spend much money on fertilizers. With cabbage at $10 per ton one would not be justified in a heavy expense for fertilizer, but when it sells for $50 to $100 per ton as is common with early cabbage, $40 per acre for fertilizer is not too great a cost, provided the yield is likely to be considerably increased. With peas, tomatoes, and sweet corn grown on contract for the cannery, one cannot justify as great expense for fertilizers as he could if he were growing the same crops for the general market.

LIME

Lime is used mainly as a soil amendment, especially to neutralize acidity although calcium, the important element in lime, is a nutrient. The use of calcium by the plant has been discussed on page 56. In addition to neutralizing acidity directly, lime may be of value by rendering harmless certain toxic materials in the soil, such as soluble aluminum, or organic materials.

Soil Reaction.—Most plants are influenced markedly by the reaction-acidity, or alkalinity, of the soil. Acidity may be expressed as total acidity (potential acidity) or by hydrogen-ion concentration. Total acidity (titratable acidity) is measured by titration with a base and this measures the quantity of H ions that can be made to combine with a base. Determining the H-ion concentration gives a measure of the H ions that are present in a given system at a given time; *i.e.*, it is a measure of the free H ions. A normal solution of two acids have the same titration values or the same total acidity, but very different H-ion concentration owing to difference in dissociation. For example, in a tenth normal solution of hydrochloric acid nearly all of the H ions are active while in a tenth normal solution of acetic acid less than one per cent of the H ions are active. These two solutions have the same total or titratable acidity.

Soil reaction is expressed in terms of pH, which may be defined as the logarithm of the reciprocal of the H-ion concentration. Water is the common solvent and since it dissociates into H^+ and OH^- ions, one of which is characteristic of acids, and the other of bases, the dissociation constant is very important. This constant is approximately 1×10^{-14}. Neutrality is the point at which H and OH ions are in equilibrium so that, at this point, the H-ion concentration equals 1×10^{-7}. In expressing H-ion concentration in terms of pH only the exponent is used, therefore pH 7 means 1×10^{-7} and represents neutrality. At neutrality there is one gram of hydrogen in solution in about 10,000,000 liters. It is essential to remember that the pH scale is a logarithmic one. For each decrease of one unit on the pH scale the H-ion concentration increases tenfold. For example, the concentration of H ions is ten times greater in a solution of pH 6 than in one of pH 7; and one hundred times greater in a solution of pH 5 than in one of pH 7. The fractions of the pH scale also represent logarithmic values.

Response of Vegetable Crops to Soil Reaction.—Vegetable-crop plants vary greatly in their response to the reaction of the culture medium. Results of many experiments indicate that most vegetable crops thrive better in a soil that is slightly acid than in a soil that is neutral or alkaline. The reaction of the soil determines to some extent the nutrient balance and toxic conditions. It is difficult to maintain nutrient balance in a neutral or alkaline soil, and in a highly acid soil aluminum or iron may become toxic. Some crops are tolerant to acidity or to conditions accompanying acidity, while others seem to be intolerant. In many cases, poor growth of plants in an acid soil is not due to acidity itself, but to aluminum toxicity. As the acidity of such soils increases the active aluminum increases.

It is not possible to give the optimum soil reaction for any crop under all conditions, because the character of the soil, the humus supply, the moisture supply, and other factors may influence the response of the crop to soil reaction. Results of many experiments conducted on a large number of soil types indicate that vegetable crops may be classified roughly as to their response to soil reaction. Such a classification or grouping is given in Table VII.

Table VII.—Classification of Vegetables According to Range of Reaction for Satisfactory Growth

pH 6.0 to 6.7	pH 5.5 to 6.7	pH 5.2 to 6.7	pH 4.8 to 5.4
Asparagus Beet Bush Lima bean Cauliflower Muskmelon (Cantaloupe) Parsnip Spinach	Bean, snap Cabbage Celery Cucumber Onion Pea	Carrot Large Lima bean Radish Sweet corn Sweet potato Tomato Turnip	Potato

The grouping given in Table VII indicates the range of reaction over which the crops might be expected to make satisfactory growth when other factors are favorable. Under some conditions satisfactory yields are obtained on soils with a lower pH or a higher pH than the range given. In most cases, however, higher yields would be obtained within the ranges mentioned than at either a lower or higher pH, provided other conditions are the same. The potato plant produces satisfactory yields over a wide range of reaction, but where the scab organism is present in the soil injury is severe at reactions between about pH 5.5 and pH 7.0.

Crops may be benefited indirectly by liming an acid soil due to the effects of the lime on the decomposition of organic matter through making conditions more favorable for the organisms; to its effect on the growth of nitrogen-fixing bacteria associated with leguminous plants; and to the effect of lime on rendering harmless certain toxic substances, such as aluminum. Cabbage and other cruciferous crops may be benefited by liming due to the effects of neutralizing the acidity on the organism causing club root. This organism, a slime mold, thrives only on an acid soil.

Effects of Overliming.—Under some conditions completely neutralizing the acidity results in reduced yields, even with crops that are intolerant to acid-soil conditions. In many cases, when the acidity of the soil is reduced to near the neutral point by liming, chlorosis or other malnutrition troubles develop due to the fact that some essential element is rendered unavailable to the plant. The availability of manganese, iron, boron, and other minor elements is affected by lime.

Applying lime to a soil that is to produce potatoes is likely to be detrimental if the reaction of the soil is pH 5.4 or higher and the scab organism is present. This organism does not thrive on soils that are highly acid, but it should be kept in mind that the potato plant does not make its best growth on a strongly acid soil. Wessels (1932) has shown that when the acidity of a silt loam soil on Long Island is greater than pH 4.6 the yield is greatly reduced. Other investigators have obtained similar results. The injurious effects of lime on crops grown on a soil that is only slightly acid probably is due largely to its making unavailable some essential element.

Forms of Lime.—The forms of lime commonly used are ground limestone (calcium carbonate, $CaCO_3$); burned lime (calcium oxide, CaO) which is made by burning calcium carbonate, the burning setting free CO_2; and slaked lime or hydrated lime (calcium hydroxide $Ca(OH)_2$). Burned lime and slaked lime are known as caustic lime. Slaked lime is formed from calcium oxide and water, $CaO + H_2O \rightarrow Ca(OH)_2$. When burned lime is exposed to the air it takes up water and gradually changes to the hydroxide or hydrate form. The change is rapid if the burned lime is exposed to rain, or if water is applied artificially.

One hundred pounds of calcium carbonate on burning loses 44 pounds of carbon dioxide (CO_2) leaving 56 pounds of calcium oxide or burned lime. Therefore, 56 pounds of unslaked, burned lime is equivalent to 100 pounds of limestone. On slaking, 56 pounds of burned lime takes up 18 pounds of water, making 74 pounds of hydrated lime equal in calcium-oxide content to 100 pounds of calcium carbonate. Both calcium oxide and calcium hydroxide on exposure take up CO_2 from the air, and change back to the carbonate form according to the following reactions: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$ and $CaO + CO_2 \rightarrow CaCO_3$.

These forms of lime differ materially in speed of action in the soil, the caustic limes being much quicker in action than the limestone. Burned and slaked lime may correct acidity within a few days, while limestone may require several months if the lime requirement is high. The speed of action of limestone depends on the degree of fineness. For reasonably quick results with limestone, 50 per cent should pass through a 100-mesh sieve (100 to the inch) and more than 90 per cent should pass through a 20-mesh sieve.

Land plaster or gypsum (calcium sulphate) is sometimes used in the place of lime, but it does not take the place of any of the forms of lime in correcting acidity. It never neutralizes acidity, but rather increases it. The calcium of this compound is removed from the soil leaving sulphuric acid behind to combine with some other base.

Application of Lime.—The quantity of lime to apply depends on (1) the soil reaction, (2) the crop or crops to be grown, (3) the kind of soil, and (4) the form of lime. Before using lime in any great quantity one should determine the lime requirement by one of the several methods available. Obviously the rate of application should be higher on a soil that is very sour than on one that is only slightly acid. It has been pointed out that crops differ widely in their tolerance to acidity; therefore, liming would not be desirable for many crops grown on soils that are only slightly acid. The kind of soil is of importance because some soils such as clays, silts, and mucks are highly buffered, while sands and sandy loams have little buffer action. Crops grown on the lighter soils are more likely to be injured by acidity than where grown on the highly-buffered soils having the same total acidity. On the other hand, there is more danger of overliming the sandy and sandy-loam soils than there is with the other kinds mentioned. There is less danger of injuring crops with ground limestone than with the caustic forms, because the former is slower in action than are the others.

In applying lime it should be kept in mind that the elements of value are calcium or magnesium, or both, and the quantity to use should be based on the proportion of these to the other chemical elements in the compound. Assuming that the different forms are of equal purity, to determine the quantity of slaked lime equivalent to a given quantity of burned lime, multiply the number of pounds of the latter by 1.3; to determine the quantity of ground stone equal to a given quantity of burned lime, multiply the latter by 1.8. These figures are based on the proportion of calcium in the compounds $Ca(OH)_2$, CaO, and $CaCO_3$.

Lime may be applied by hand with a shovel, with the fertilizer attachment of a grain drill, or with a fertilizer or lime sower. Hand application is hard, dusty work and it is difficult to get good distribution by this method, especially where only a small quantity is to be applied. The grain drill is satisfactory where only a few hundred pounds are to be applied to the acre. Use of the lime sower is the best means of applying lime since the machine is made for this purpose and can be regulated to sow at any rate desired. This method is the most rapid and most economical.

When lime is applied on the surface it should be harrowed in thoroughly. Lime and fertilizer should not be applied at the same time because the lime may reduce the quantity of available phosphates and result in loss of nitrogen from salts of ammonia. It is desirable to apply lime at least a week in advance of planting a crop; several weeks in advance is not objectionable. In fact, when ground limestone is used it is desirable to make the application several weeks, or even a few months, in advance of planting a crop because of the slow action of the carbonate form.

CHAPTER VII

SEEDS AND SEED GROWING

Good seed is essential to success in vegetable growing. The most careful and efficient gardener cannot achieve success with poor seed, even if he gives the closest attention to all other factors of production. Since the cost of seed is such a small item in the total cost of production of most vegetable crops the grower cannot afford to take any more chances than necessary. The best seed obtainable should be used.

What Is Good Seed?—Seed to be classed as good must be (1) clean, (2) viable, (3) free from disease, and (4) true to a good name. Seed to be classed as clean must be free from weed seeds, dirt, and other foreign matter. Most vegetable seed is relatively free from impurities, though occasionally it is not well cleaned and contains too much dirt and refuse.

Good seed is viable. It must have sufficient vitality to complete the process of germination. To do this, it must be able to nourish the embryo plant until it can support itself independently of the supply of food stored in the seed. This means more than mere sprouting. Vegetable growers have little trouble with this problem as very few of the better seed houses put out seed of unduly low vitality. Most seedsmen make germination tests of their seeds to be sure that they are viable.

Seed should be free from disease. Some diseases, as black rot of cabbage, are carried on the seed coat and can be controlled by seed treatment; others are carried within the seed coat. Some, such as the anthracnose of beans, are not successfully controlled by seed treatment. Blackleg, carried within the seed of cabbage and cauliflower, can be fairly well controlled by hot-water treatment as discussed in connection with disease in Chap. XIX.

Seed should be true to a good name, that is, it should be true to type for the variety in question. This point is of prime importance and is the one which gives the vegetable grower the greatest concern.

Definition of Terms.—A horticultural classification of vegetables recognizes the following gradations: (1) the kind, (2) the variety, (3) the strain, and (4) the stock. Work (1925) gives the following definitions of these terms:

> KIND.—A kind includes all the plants, which, in general usage, are accepted as a single vegetable, as for example, tomato, cabbage, bean. This is not the same as the genus or the species of botanical classification. The species, as

Brassica oleracea includes several kinds—cabbage, cauliflower, and others. The beans come from more than one species.

VARIETY.—A variety includes those plants of a given kind which are practically alike in their important characteristics of plant and product. Each variety should be distinct in one or more prominent and significant features. Named varieties that are not distinct should be classed as strains of a recognized variety, or as mere synonyms.

The line between varieties is not sharply drawn and is mainly a matter of informal consensus of opinion. There is need for the establishment of some generally accepted authority and steps have been taken in this direction by the U. S. Department of Agriculture in publishing descriptions of standard varieties of the important vegetable crops. These publications, of which four had been issued by 1939, are commonly accepted as "Type Books." The studies of standard varieties are made by the U. S. Department of Agriculture in cooperation with the experiment stations of the various states. Varieties of each crop studied are grown from the same seed stock in several representative regions of the United States and descriptions are made in each region. The published descriptions represent a composite of the descriptions made in the several regions and by several workers.

STRAIN.—A strain includes those plants of a given variety which possess its general characteristics, but which differ from others of the variety in one important, or two or three minor respects—difference not great enough to justify a new variety name. Thus Red Kidney is a standard variety of bean. Wells Red Kidney is an anthracnose-resistant strain of this variety . . . The distinction between variety and strain is based simply on degrees of difference.

STOCK.—A stock represents all plants of the same parentage or pedigree. Differences between various stocks of a variety or strain should be very slight. A seed grower may maintain more than one stock of a strain, each representing a single pedigree line. Two seed growers may have stocks so nearly alike as to be indistinguishable, but as long as they are separately maintained, they are distinct stocks.

The distinctions of these definitions are not hard and fast; in fact, the seed trade is anything but consistent in its use of terms. The idea of a stock as distinct from a strain is based on the concept of parentage or pedigree lines. While some seed houses practically ignore the pedigree idea, many keep careful records and are able to trace parentage through several generations. At the same time, stocks of presumably nearly equal excellence are often used interchangeably.

BUYING SEED

Seed growing is a technical and highly specialized business carried on largely in regions particularly adapted to the production of special crops. Because of these facts most vegetable growers should buy all of their seeds and practically all growers should buy most of their supply. In buying, it is usually desirable to get the best seed available, making the cost a secondary consideration. Cheap seed is usually the most expensive in the long run. The vegetable grower should obtain all the information possible on reliable sources of seeds of the varieties and strains of all the crops he grows. Seed source and strain tests conducted by the experiment stations have shown great variations in yield, in earliness, in uniformity, and in other important qualities. This is true for most varieties of all of the important kinds of vegetables. After getting such information as is available, the grower would do well to determine for himself on his own land the varieties and strains that prove most satisfactory.

Growers should buy only from reliable dealers, those that have a good reputation to maintain. Commercial growers would do well to deal mainly with houses that cater especially to producers like themselves. Most reliable seed houses make a specialty of some crop or crops and usually the seedsman who gives special attention to a particular crop develops and maintains superior strains. It usually pays to buy from seedsmen who take pride in certain crops. The better growers have learned to buy from specialists so that it is not at all uncommon for a gardener to buy tomato seed from one house, cabbage seed from another, sweet corn from a third, and so on.

In buying seed it is well to buy as near the source as possible. The originator, the introducer, or the specialist is more likely to use greater care in maintaining good stocks than is a dealer who has no special interest in the variety or strain. This is not always true as the originator may, after a time, become careless while another grower may maintain or even improve the stock. Seed dealers have learned that certain seed growers and wholesalers have superior stocks. Some vegetable growers are beginning to learn these sources and inquire for them when buying seed. This trend toward seed of known origin is a wholesome one and should be encouraged. When dealers carry more than one stock of a given variety the buyer should ask for the stock number. This would make it possible for him to get the same or a different stock the next year, depending on whether it proved satisfactory or unsatisfactory.

Buying in Advance.—With some crops the cost of seed is small in comparison to the total cost of production so that the grower cannot afford to take chances on getting a poor strain or one unsuited to his needs. With crops like celery, cabbage, and cauliflower, it pays to buy seed a year in advance and test it on a small scale alongside the main planting the first year. If it proves to be true to type and performs well, the grower is assured of having what he wants the next year. Should the seed not be satisfactory the grower has at least saved the labor incident to planting and tending a poor crop. Loss of seed is small in comparison to loss of a crop. When dealers know that gardeners are testing the seed in advance for performance, they are not going to take chances on supplying inferior stock.

With crops such as onions, parsnips, and perhaps sweet corn, it is not safe to buy in advance because the seed of these do not retain their vitality very long. Peas and beans are bulky and the cost per acre for seed is too great to permit purchase a year ahead. In both of these cases, and in others, samples may be obtained for tests from reliable houses and stock numbers or other designations obtained so that the stock may be identified the next year.

Cost of Good Seed.—Growing good seed is expensive. Seed users must, therefore, stand ready to pay the price for a good product. This does not mean that a high price in itself means high quality or that one should pay more than good seed is worth. With most crops the cost of seed to plant an acre is so small that a difference of 25, 50 or even 100 per cent is hardly significant, provided, of course, greater value is offered for the higher price. The practice of sending the same seed lists to several houses, asking for quotations, and placing the order where the total is lowest is the poorest kind of business. There is no basis of comparing prices unless it is known that the products are of equal quality, and in most cases this is not known in buying seeds.

Certified Seed.—Many states now provide certification service for recognized varieties of many kinds of vegetable seeds. Crops being grown for certification are inspected two or more times during the period of growth for seed-borne diseases and for trueness to type. Inspections are made usually by specialists of the State College of Agriculture, State Experiment Station, or the State Department of Agriculture, and certificates are issued to the seedsmen by some official agency. These certificates are attached to the bags or other containers used for the seed certified.

Each state usually publishes rules and standards that must be met before the certificates are issued. Buyers of certified seed should read carefully the statement of scope of certification because the standards are not the same in the various states. Greater uniformity in certification standards is very desirable and, while it might not be feasible to have the same standard's apply to all regions, it would be practicable for the states within a region to have the same rules and standards.

VARIETY AND STRAIN TESTING

Testing for trueness to type and for performance is of much greater importance than testing for purity and germination since growers suffer little loss from impurities or from low germination. Most vegetable seeds are clean and have at least fair vitality, but very often the crop produced is not true to type. Some testing of varieties to find those suited to the growers' needs is essential, but after this is determined most attention should be paid to the testing of strains and stocks of the varieties selected.

Great differences in yield, earliness, and other performance characters exist between strains of the same variety of most crops, and it is only by trial that the superior strains are found. Work (1925) has reported the yields and returns from two strains of Copenhagen Market cabbage, which were in a strain test conducted by the Department of Vegetable Crops at Cornell University for 3 years. These data illustrate the importance of selecting strains for earliness where this is important, or for high yield when that is the most important. These two strains were obtained from reliable seedsmen. One strain produced a small, compact head and was early, while the other was late, produced a large head and a heavy yield. The average yield per acre was 10.75 and 15.05 tons respectively and the returns were $492 and $366 per acre. In other words, the strain producing the lower yield gave a return of $126 more than the high-yielding one, due simply to earliness. Where earliness is not a factor, the heavier yielding strain would be preferable, unless the market demanded small heads. Mack, Stout, and Haller (1935) reported results of tests conducted in 1933 and 1934 of 14 strains of Golden Acre cabbage in which there was a range of from 127 to 151 days from seed sowing to maturity and the average weight of head varied from 1.87 to 3.04 pounds. Golden Acre is considered as a strain of Copenhagen Market. If all of the 24 strains of Copenhagen Market, including Golden Acre, are considered, the variation in days to maturity was from 127 to 171 and the range in average weight per head was from 1.87 to 4.10 pounds. These two illustrations show the importance of selecting strains on the basis of market demand.

While the commercial gardener should make his main plantings of tested and reliable strains and varieties, he should be on the lookout for new and promising things. These should be tested on a small scale for it is only by trying new or so-called new varieties and strains that the best is discovered. The grower who depends on the highly advertised novelties for his main plantings usually fails. A good rule to follow is to try the new while making a living from the old reliable strains. The grower producing only a few kinds of crops can well afford to try the new listings for now and then he will find something of distinct merit. He should not be led astray by extravagant language in the catalog description, but should learn to discriminate between "selling talk" and information as to the value of the thing advertised. He should learn to discriminate between statements of opinion and statements of facts.

SEED GROWING

Seed growing is a highly specialized business requiring particular knowledge and skill not possessed by many vegetable growers, therefore most gardeners should buy their seeds through the regular channels. Seeds of many crops are grown commercially in regions where the soil and climate are especially favorable and some are produced in foreign countries, where the ecological factors are favorable and, in addition, where labor is cheap. Some seed crops can be produced most satisfactorily in a dry climate. Others like cabbage, cauliflower, and other Brassicas grow best in a relatively cool climate. California is an important seed-growing state because the climatic conditions are almost ideal for the harvesting, curing, and handling of seeds of many crops. In humid regions, many seed crops grow satisfactorily, but there is danger of loss at harvest time, hence a dry region is preferable, other things being equal.

While most vegetable growers should purchase a large part, if not all, of their seeds, there are many progressive men who are growing all of their seeds of certain crops and finding it profitable. Before undertaking to grow seed, the grower should weigh carefully the advantages against the disadvantages. He should be fitted by temperament, knowledge, skill, and situation to do it well, for if the demands are not worth meeting effectively, he had better buy the seed.

Advantages.—The man who grows his own seed knows its origin and parentage. He is able to select according to his own ideal and to suit his own conditions. Commercially grown seed is sold on all markets and the individual should find an advantage in selecting to suit his local climate, soil, and market. One who grows seed learns to know the crop and the plant that produces it. This applies to the details of culture and management of the crop as well as to the characters of the plant itself. Few enterprises offer more in the way of personal satisfaction than seed improvement for the man who is fitted by temperament and training to do the work well. If the grower produces a strain of seed that is better than other strains, he will find that other growers will be willing to pay a good price for his product. Some growers have developed a good paying sideline in the growing of high-grade seed of some special crop.

Disadvantages.—The disadvantages of seed growing outweigh the advantages in most cases. Seed growing is exacting work. It competes with other work at critical times in the vegetable-growing business. It calls for knowledge of the principles of plant breeding, of the technique of growing seed crops, of curing and handling seed. It calls for keen observation, and aptness in judging and comparing type and performance. It requires close application to details, such as keeping biennial plants over winter, and avoiding danger of crossing in the field.

In seed growing one of the serious problems is to isolate the seed plots so that crossing will not take place. Some crops, as beans, Lima beans, peas, lettuce, and tomatoes are normally self-pollinated, and different varieties may be grown close together for seed without much danger of crossing. Others are normally cross-pollinated and varieties and closely related species should be segregated. Among the vegetable crops that are normally cross-pollinated are cabbage, cauliflower, kale, kohlrabi, turnip, radish, carrot, beet, cucumber, muskmelon, watermelon, squash, pumpkin, parsnip, corn, spinach, salsify, and okra. Cabbage, cauliflower, and the other Brassicas mentioned readily cross with each other if they happen to be in blossom at the same time. Muskmelons do not cross with cucumbers as is commonly believed, or with other cucurbits. Watermelons cross with the citron melon but not with other cucurbits. Pumpkins and squashes belonging to the same species cross readily. Parsnip crosses with wild parsnip.

In growing seed of crops that readily cross, it is necessary to have considerable land if seed of several varieties is to be grown, or if several of the Brassicas are to be grown. The distances necessary to separate varieties depend on the crops, especially their method of pollination, whether by wind or insects. The kind of insect pollenizers also needs to be considered for some travel only a short distance, while others go long distances. Wind-blown pollen from corn may be carried a considerable distance.

The beginner in seed growing would do well to start with crops that are easily handled, especially such crops as corn, tomatoes, beans, peas, and the cucurbits. All of these crops are annuals so do not need to be carried over winter. He should not attempt to grow seed where the climatic conditions are very unfavorable to production, harvesting, and curing. Not more than one variety of any crop that readily crosses should be grown unless sufficient land is available to enable the grower completely to isolate his plantings.

Since seed growing is a subject in itself it is not within the scope of this book to do more than point out a few of the factors that should be considered before undertaking the work. Those interested in seed-growing methods are referred to special books and bulletins on the subject.

RELATION OF SIZE OF SEED TO CROP YIELD

Many experiments have been conducted during the past 30 or 40 years to determine the effect of the size and weight of seed on yield. In some of the experiments the size only was considered, in others weight only, and in still others both size and weight. The data from the experiments are conflicting. Some show an advantage for large seed, and others for medium-size seed as compared to either the small or the very large.

It seems evident, from a study of the experimental data published by Cummings (1914), Schmidt (1924), Rotunno (1924), Hoffman (1925), and Kotowski (1925), that size of seed is not of great importance if the abnormally large and the very small seeds are not considered, and these usually do not constitute a large proportion of most commercial seed. Rotunno obtained results that showed varietal differences with reference to the effect of size of seed on yield of radishes. Results of experiments by Hoffman with sweet corn of the Country Gentleman variety showed that large seed produced a better stand and reached canning stage about five days earlier than small kernels from the same ears. Sayre (1928) obtained similar results.

In general, it may be said that the main advantage in separating seed into different sizes is to insure even distribution in planting by machines, and in evenness of maturity of sweet corn and, perhaps, some other crops. When the seed varies greatly in size, it is desirable to separate the sizes in order to obtain even distribution with the crops grown from seed planted where the crops are to mature. Evenness of maturity is of importance in growing sweet corn for the cannery and, when there is much variation in size, it is desirable to separate the sizes by screening it. Each size can then be planted separately. In growing corn for the canning factory, evenness of maturity is important because of the desirability of harvesting any given lot at one picking, if possible.

With most vegetable crops the very small, immature seed should be discarded when it makes up any considerable portion of the total. It should be borne in mind that good breeding is of much greater importance than size of seed. It is possible that large seed, in some instances, is produced on low-yielding plants and, in such cases, it would produce a lower yield than smaller seed produced on large-yielding plants. In fact, this is the probable explanation for large, heavy seed producing a lower yield than small seed. Large seed, if well developed and mature, has more reserve food than small seed of the same specific gravity and this reserve food would not be a disadvantage. Unless an investigator uses pure lines in his experiments on size of seed he is not certain that the large and the small seeds have the same genetic constitution.

LONGEVITY OF VEGETABLE SEEDS

It is well known that seeds of some vegetables retain their vitality longer than seeds of others. For example, seeds of cucumber, squash, muskmelon, and lettuce retain their vitality longer than those of carrot, parsnip, parsley, and onion. It is also known that any kind of seed retains its vitality under some conditions better than under others. In some sections of the South and in the tropics it has been found that seeds, kept under ordinary storage conditions, do not retain their vitality for very long periods. Poor keeping under these conditions has been attributed to high temperature and to high humidity. Studies made by Duvel (1904) indicate that humidity is the main factor. He made germination tests of seeds of several kinds of vegetables stored in various sections of the United States. After the seeds had been stored for 128 and 251 days, germination tests were made to determine the loss in viability. A comparison of the percentage of germination of seeds of the several kinds stored at Ann Arbor, Mich., and Mobile, Ala., will serve to illustrate the effects of climatic factors on viability. This comparison is given in Table VIII.

TABLE VIII.—EFFECT OF CLIMATE ON VITALITY AS SHOWN BY PERCENTAGE OF GERMINATION
(Adapted from *B. P. I. Bull.* 58)

Kind of seed	Stored at Ann Arbor, Michigan		Stored at Mobile, Alabama	
	128 days	251 days	128 days	251 days
Sweet corn "A"	100.0	98.0	80.0	20.0
Sweet corn "B"	92.0	80.0	48.0	12.0
Onion	95.0	97.5	7.0	0.0
Cabbage	96.0	91.0	64.5	17.0
Radish	82.5	77.5	58.5	51.0
Carrot	76.0	86.0	59.0	8.5
Pea	90.0	98.0	69.2	44.0
Bean	98.0	100.0	58.0	0.0
Tomato	89.0	98.0	90.0	79.5
Watermelon	100.0	96.0	98.0	64.0
Lettuce	82.0	92.5	63.0	20.0

It will be observed that the percentage germination was much higher for seed stored at Ann Arbor than at Mobile, with the exception of tomato at the end of 128 days. At the end of 251 days only the tomato and watermelon stored at Mobile had even a fair germination. The onion seed was practically worthless at Mobile at the end of 128 days storage, and most of the other kinds were low in percentage of germination. Duvel attributed the low vitality of the seed stored at Mobile to high humidity. He found a close correlation between the rainfall and the loss in vitality of the seeds. The deterioration was proportional to the rainfall, and was more apparent as the temperature increased. However, the loss in vitality due to increase in temperature is dependent on the quantity of water present. In other words, where the humidity is low, a rise in temperature within reasonable limits has very little effect on vitality, but with high humidity a rise in temperature hastens deterioration. Duvel carried on some experiments under controlled conditions in sealed bottles and in packages with definite quantities of moisture and at various known temperatures. The results of these experiments show a close relationship between loss in vitality and the increase in water content, the deterioration increasing also with the temperature.

TABLE IX.—LENGTH OF TIME SEEDS MAY BE EXPECTED TO RETAIN THEIR VITALITY WHEN PROPERLY HANDLED

Kind of vegetable	Years	Kind of vegetable	Years
Asparagus	3	Parsley	3
Bean	3	Parsnip	1
Beet	4	Peas	3
Cabbage	5	Pepper	4
Carrot	3	Pumpkin	4
Cauliflower	5	Radish	5
Celery	6	Salsify	2
Cucumber	5	Spinach	5
Eggplant	6	Squash	5
Kale	5	Sweet corn	1
Lettuce	5	Tomato	4
Muskmelon	5	Turnip	5
Okra	2	Watermelon	5
Onion	1		

Barton (1935) reported results of storage experiments on carrot, eggplant, lettuce, onion, pepper, and tomato seed stored at room temperature and at −5°C. Some lots were air-dried and stored open, some air-dried and sealed, others dried over CaO to remove about one-third of the moisture, still others mixed with CaO to remove one-third and one-half of the moisture. Those lots that were dried by using CaO were all sealed. Eggplant and tomato seeds kept well for three years in all of the conditions tried. Carrot, lettuce, onion, and pepper seeds were injured by sealed storage at room temperature unless they had been dried. At −5°C. drying was not necessary. Dried, sealed storage was superior to open storage at room temperature. Germination of lettuce seed remained constant throughout the three years of storage. Miss Barton concludes as follows:

> Results of these tests indicate that open storage at room temperature in regions of the same general temperature and humidity as Yonkers, N. Y., would effectively maintain vitality for two years in a majority of cases. However if the moisture content of the seeds is reduced to approximately 6 per cent, and sealed containers are used, vitality is assured for at least three years. No drying is necessary if cold storage is used.

Seeds to keep well in storage must be mature, thoroughly cured and stored in a dry place. The temperature is not an important factor if the moisture content is kept low. Under good storage conditions fresh seed of some kinds may be kept for many years. Table IX gives an idea of how long it is safe to keep seeds of several kinds of vegetables under reasonably good storage conditions.

In considering the data in Table IX it should be kept in mind that seed may be old when it is purchased by the gardener. If it is old or if it has been stored under unfavorable conditions, it would not retain its vitality as long as indicated in the table.

Seed Testing.—The term "seed testing" is ordinarily used in connection with purity and viability. Since vegetable seeds are fairly free from impurities, testing for purity is not of much value, but testing for viability or germinating qualities is important, for such a test may be the means of avoiding losses due to sowing seed of low germinating power. By making a germination test the gardener knows how much seed to plant to get a good stand and may save time by avoiding the necessity of replanting. Seed kept over from one year to the next should always be tested for germination before planting, because some seeds completely lose their viability in one year and many others lose considerably in vitality and produce weak plants. Perhaps the best method for the vegetable grower to use in making a germination test is to sow the seed in soil in a seed flat or seed pan. The seed should be counted, then planted in rows, and covered to the proper depth with soil. The flats or pans of seed may be placed in a greenhouse, in a hotbed, or in a moderately warm place in the dwelling. The soil should be kept moist but not wet. Counts made of the plants that come through the soil will give the gardener a good idea of what might be expected of the seed when planted under favorable conditions in the field. A simple method of making a germination test is to count out 25, 50, or 100 seeds of the sample to be tested and to place these between folds of moist blotting paper or moist cloth (cotton flannel). The blotting paper or cloth is placed in a soup plate and another plate is inverted over the lower one to prevent rapid drying. The seeds should be placed in a warm room and kept moist, but not wet, by sprinkling. As the seeds sprout they are counted and thrown away. The rapidity of germination and the vigor of the sprout should be noted, for seeds which germinate very slowly and produce weak sprouts may fail to produce plants when planted outside.

Temperature and Germination of Seed.—It is fairly well known that some kinds of vegetable seeds will not germinate at low temperatures, and that some will rot in cold soil. Kotowski (1926) reported results of studies of the effects of temperature on the germination of 17 different kinds of vegetables, representing 8 families. The seeds were planted in coarse quartz sand in flats in electrically controlled, constant-temperature chambers. The seeds used were onion, beet, spinach, radish, cabbage, cauliflower, pea, garden bean, Lima bean, carrot, parsley, tomato, eggplant, pepper, muskmelon, cucumber, and lettuce. The temperatures used were 4°, 8°, 11°, 18°, 25°, and 30°C.

In general the speed of germination of all kinds of seeds used in this experiment increases as the temperature rises, but at the lower temperatures the percentage germination of spinach, lettuce, cabbage, parsley, and beets was higher than at high temperatures. From this point of view the optimum temperature for spinach was 4°C., for cabbage 8°C., and for beets 11°C. Only lettuce, spinach, radish, and pea germinated at 4°C. At 8°C. all except tomato, eggplant, pepper, cucumber, melon, garden bean, and Lima bean germinated. These did not germinate at 11°C., although the garden bean developed radicles but no hypocotyl. All seeds germinated at 18°C. and, all except lettuce, at the higher temperatures, but the speed of germination was slow at 18°C. for all of the warm-season crops—tomato, eggplant, pepper, cucumber, melon, bean, and Lima bean.

The minima for beets, onions, cabbage, cauliflower, carrot, and parsley are between 4° and 8°C. The minima for eggplant, peppers, cucumber, melon, and beans are between 11° and 18°C.

The viability of tomato, eggplant, pepper, cucumber, melon, and garden bean was not affected by temperatures of 11°, 8°, and 4°C., for these seeds germinated after being in the germinating chamber at these low temperatures for 35, 45, and 60 days, when placed in chambers held at 30°C. The Lima bean is the only seed that rotted when held at temperatures too low for germination. Lettuce did not germinate at 30°C.

Borthwick (1925) found that asparagus seed did not germinate in 17 days at 10°C., while at 20°C., 27 per cent germinated in the same length of time, and at 25°C., 98 per cent germinated in 8 days. At 40°C. there was no germination. Borthwick expressed the opinion that the low rate of water absorption at the low temperature accounts for slow germination. He showed that water was absorbed very slowly at 10° and increased rapidly as the temperature was raised to 18°, 22°, 30° and 40°C. See discussion in Chap. XVI.

Results of these and other experiments explain why it is feasible to plant some seeds in cold soil and not feasible to plant others under the same conditions. It is not safe, however, to plant many kinds of seed in the field when the soil is too cold to permit of germination because, under average field conditions, disease organisms are likely to be present and the soil may become so compacted that seedlings would have difficulty in breaking through the crust. Insects and other animal parasites might also injure the seed.

CHAPTER VIII

PLANT GROWING AND PLANT-GROWING STRUCTURES

Certain vegetable-crop plants are started in specially prepared beds and the young plants later transplanted to the field or garden. Among these vegetables are cabbage, cauliflower, brussels sprouts, celery, tomatoes, eggplants, peppers, sweet potatoes, and others. Whether these are started in outdoor beds or under the protection of greenhouses, hotbeds, or cold frames depends on the region and the time of the year they are grown. In the North all of these are started in some kind of a plant-growing structure when grown as early crops, and even in sections of the South hotbeds and cold frames are used to some extent. Other crops, such as lettuce, melons, cucumbers, beets, onions, and even Lima beans and sweet corn, are sometimes started in hotbeds, cold frames, or greenhouses.

There are many advantages in starting plants in greenhouses or other forcing structure, the most important being (1) increasing the length of the growing season by planting seed several weeks before weather would permit of outdoor planting; (2) making it possible to grow long-season, tender crops such as tomatoes, peppers, eggplants, melons, and Lima beans in regions having a relatively short-growing season; (3) production of an earlier crop thereby getting advantage of the early market; (4) enabling gardeners to produce more crops on the same land; (5) protecting young plants from unfavorable conditions, and disease and insect injury; (6) obtaining larger yields of many crops, especially the tender, long-season plants, such as tomatoes, eggplants, peppers, melons, cucumbers, and Lima beans, which continue to bear in the North, until killed by frost.

GREENHOUSES

Since greenhouse construction and management are specialized subjects taught in special courses in most agricultural colleges, the greenhouse is discussed here only from the standpoint of use by the market gardener and the truck grower as an adjunct to his outdoor gardening. Many up-to-date market gardeners and truck growers in the North have, at least, a small greenhouse for use in starting plants during winter and early spring. The use of greenhouses for this purpose is increasing. Some vegetable growers combine vegetable forcing with their outdoor gardening. They have entered the forcing business by utilizing the greenhouse for growing crops to maturity when the space is not needed for starting plants. This, however, is not practicable where only one small plant house is available.

Advantages of Greenhouses.—In the North the greenhouse is far superior to the hotbed or to the cold frame for starting plants. Some of the advantages are: (1) the temperature can be more easily controlled in greenhouses than in other forcing structure, (2) the ventilation can be regulated much better and there is much less danger of chilling the plants, (3) the facilities for work are better in a greenhouse than in hotbeds, (4) the plants can be watered and otherwise cared for better and at less expense in greenhouses than in hotbeds and cold frames. During early spring there is danger of chilling plants in hotbeds when the sash is removed for watering, transplanting, and care. There is no such danger in greenhouses. The use of greenhouses for growing crops to maturity has many advantages for the market gardener, provided there is a local demand for greenhouse products at satisfactory prices. Growing vegetables in greenhouses in the winter enables the market gardener to keep in touch with the market during the whole year, utilizes the grower's time to good advantage, and adds to his income. While the demand for fresh vegetables during winter has increased markedly within the past few years, it must be borne in mind that more and more of these are supplied from the South, from the Southwest, and from Mexico, Cuba, Bermuda, and Puerto Rico.

Sash Houses and Other Small Greenhouses.—When a grower expects to use a greenhouse only for growing plants for transplanting, he cannot afford to build an expensive structure since it is used for only a few months each year. For this reason there is a demand for small, relatively cheap greenhouses. Many growers have built cheap frame structures and covered them with hotbed sash. While these sash houses are more expensive than hotbeds, the advantages more than balance the extra cost. Some of these houses are low structures with the eaves within a few inches of the ground level, while others have walls entirely above ground. These two types are illustrated in Figs. 2 and 3. In the low type of construction the walk between the beds is excavated to the depth of 2 or 3 feet, and the beds or benches are near the ground level. This type is more easily heated than the high type, but is less convenient for work. On poorly drained soils the low type is not satisfactory.

The high type of sash house has walls extending 2 to 4 or more feet above the surface of the ground. Some of these have solid concrete walls up to the eave plate, others have wood walls, and still others have part wood or concrete with glass above. Where considerable labor and money are expended for walls, framework, and heating systems it would be wise to build a standard type of greenhouse rather than a sash house. Th only advantage of a sash house is its low cost.

Some building concerns are making a specialty of small ready-cu greenhouses to meet the needs of the vegetable grower for plant-growin structures.

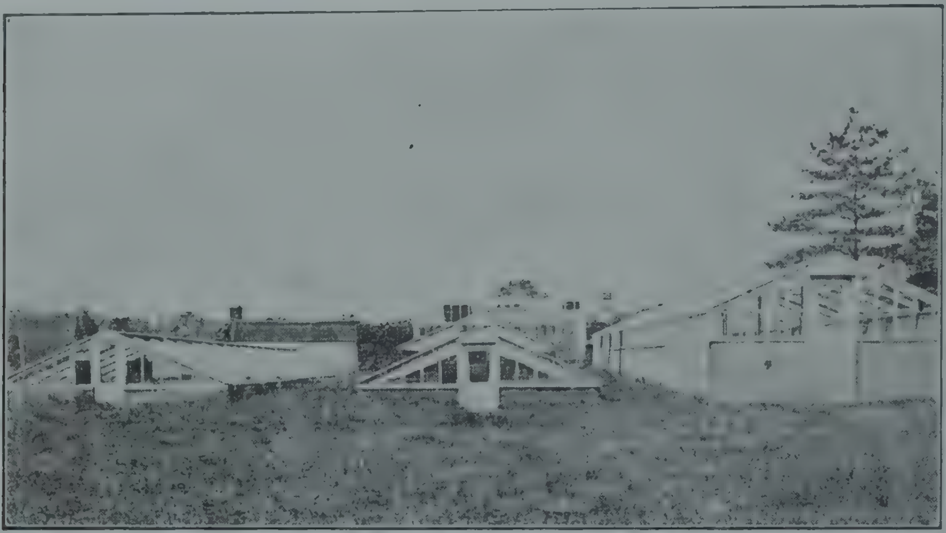

FIG. 2.—Two types of sash greenhouses, one with low walls and one with high walls. (*Courtesy of N. J. State Coll. Agr.*)

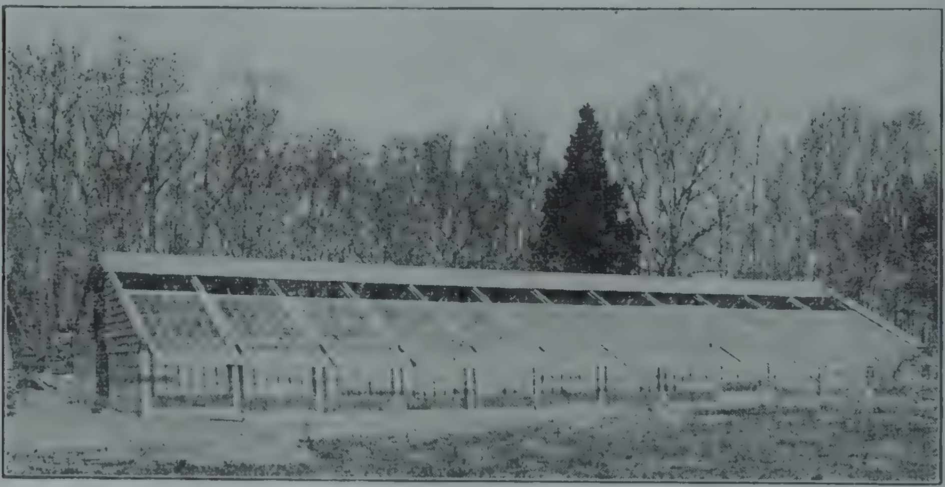

FIG. 3.—Sash house with concrete-block base, and glass in side walls. Note method o ventilation. (*Courtesy of N. J. State Coll. Agr.*)

The sash house and other small greenhouses can be heated by ho air, hot water, or steam. Steam is not feasible unless a steam-heatin system is used for other purposes. In some sections heating by mean of hot air carried through vitrified tile flues is very common. The flu is installed in much the same way as described for the flue-heated hotbed Hot-water heating is the most desirable, although it is more expensiv to install than is the flue system. Hot water requires less attention an maintains a more even temperature in the house.

HOTBEDS

Use of Hotbeds.—The main use for hotbeds is for starting plants to be grown in the garden or field, although they are used to a considerable extent to grow crops to maturity out of the normal growing season. Before greenhouses came into such general use, nearly all market gardeners depended on hotbeds for starting plants such as cabbage, tomatoes, eggplants, peppers, etc. Even where they have greenhouses most gardeners still use hotbeds. Practically all market gardeners in the North who do not have greenhouses for starting plants during winter or early spring use hotbeds for this purpose. Hotbeds are also used in many sections of the South for starting plants as well as for growing crops, such as lettuce and radishes, to maturity.

Location.—The main considerations in locating hotbeds are: (1) nearness to the farm buildings so that they can be cared for with the least trouble, (2) proximity to a good water supply, (3) protection from the cold winds by locating them on the south or southeast side of a hill, on the protected side of buildings, or by means of windbreaks, board fences, or walls. Where no suitable protection is already available a tight fence about 5 feet high is often constructed on the north and west sides of the frames.

Southern or southeastern exposures are preferable because beds will secure more sunshine with these exposures than with others. Where there is more than one row of frames they should be parallel to each other, with ample spaces between the rows for the handling of the sashes and mats. Eight to ten feet of space between the rows of frames is desirable, if the land is not too valuable.

The Hotbed Pit.—Many hotbeds are heated by the fermentation of horse manure in pits made for the purpose. The pit should be well drained so that water will not collect in it and prevent fermentation of the manure. The pit should be about the same width as the frame, which is usually 6 feet, although it will sometimes carry two rows of hotbed sash sloping in opposite directions. The depth of the pit depends on the length of time the bed is to be used, the longer the period the deeper the pit should be because more manure is needed for a hotbed to be used for three months than for one used only one or two months. Most pits are 24 to 36 inches deep. In the North more manure is used than in the South. For starting tomatoes, eggplants, and peppers more manure is needed than for cabbage, lettuce, and celery, because the latter crops do not require so high temperatures as the former. As a rule 18 to 36 inches of manure is used in hotbed pits in the North while a depth of 12 to 18 inches is sufficient for starting plants in many sections of the South.

The Hotbed Frame.—The frame may be made of wood, cement, brick, or stone, the first two materials being the most common. Where wood is used in making a permanent hotbed 2 by 4-inch lumber is used for posts. These posts are driven into the ground at the corners of the bed and at intervals of 4 to 6 feet along the sides of the bed. Boards or planks are nailed to these posts. It is desirable to use a double layer of 1-inch boards or one layer of 2-inch planks for the frame. The frame may or may not extend to the bottom of the pit, but in any case it should extend 12 to 18 inches above the surface of the ground on the back side (usually north side) and 6 to 12 inches on the front, thus affording a slope preferably to the south. Every 3 feet a crossbar or slide should be placed for the sash to rest upon. For these crossbars, 2 by 3-inch pieces are satisfactory. A ½-inch strip nailed in the center of these crossbars to prevent binding of the sash is an advantage. In all permanent hotbeds durable wood should be used. Cedar, locust, or chestnut for the posts and cypress or chestnut for the frame are satisfactory.

Concrete is being used by many gardeners for hotbed frames. This is much more durable than wood and is cheaper in the long run. In making frames of concrete the mixture is poured into forms in the usual way.

Sash.—Only the most durable wood should be used in making hotbed sash. Cypress and cedar are popular for this purpose. Sashes differ in size, but the most common size is 3 by 6 feet. A larger sash is too heavy to handle and is more subject to breakage. Most gardeners buy the sash already made, and this practice is usually wise, although it is advisable to inquire into the type of construction and the wood used.

The sash should be painted before being glazed. A good grade of glass is always desirable, although cheaper grades are sometimes used. The glass is generally lapped about ⅛ inch. Some gardeners prefer to butt the glass, but if the ends do not fit closely there will be considerable leakage. Each 3 by 6-foot sash is usually made for three rows of 10 by 12-inch glass, requiring 18 panes for each sash. Putty or mastica is applied in the rabbet of the sash bar, then the glass is pressed into it and held in place by glazing points. These materials prevent water from running down under the glass. After glazing, the sash should be painted again. Each year a coat of paint should be given to protect them against decay.

Hotbed Covers.—The ordinary hotbed covered with sash needs some protection during cold weather. It is necessary to cover the beds every cold night and sometimes during the entire day in early spring, especially for tender plants, such as tomatoes, eggplants, peppers, melons, etc. Old matting, carpets, or heavy burlap may be used, but most gardeners use straw mats. These are sold by dealers in garden supplies. but they may be made at home.

Manure-heated Hotbeds.—Fresh horse manure is used for heating hotbeds to quite a large extent, although steam, hot water, and hot air are also used. The manure must be fairly fresh or very little heat will be generated. Two parts excrement to one part straw or other litter will give good results. Manure with shavings as litter is not satisfactory.

Preparation of manure for the hotbed should begin 10 days to 2 weeks before the beds are needed. If fresh manure from the stable is used it should be placed in a flat pile about 4 feet high, 4 to 5 feet wide and any length desired. If dry at the time of piling the manure should be moistened in order to start fermentation. In 2 or 3 days the manure will begin to steam. When fermentation is well under way the pile should be turned to insure uniform heating throughout. In turning the manure, that from the interior of the pile should be placed on the exterior of the new pile. In 2 or 3 days after turning the manure should be in condition for placing in the pit.

In filling the pit the manure should be thrown in layers of 5 or 6 inches and each layer trampled fairly well, especially along the sides and ends of the pit. Since the manure will settle several inches, allowance should be made for this. Sometimes a layer of 3 or 4 inches of straw is put over the manure in order to have a more even distribution of heat and prevent "hot spots" in the soil. A layer of 4 to 6 inches of good soil is put on the manure or straw, although 2 inches of soil is sufficient if the seeds are sown in flats instead of in the soil of the bed.

Temporary hotbeds are made by placing the frames on the top of a pile of fermenting manure. The frames are usually banked with manure as protection from cold. More manure is required where the frame is set on the pile, because the pile must be considerably wider and longer than the frame. This type of hotbed is desirable where drainage is poor.

Flue-heated Hotbeds.—Hotbeds are frequently heated by hot air conducted through flues from a firebox located at one end of the beds. Flue-heated beds are very commonly used for growing sweet potato plants in New Jersey, but they are also used for growing other plants in many sections of the country. For sweet potato plants the beds used in New Jersey are open, but for growing other plants they must be covered.

A common type of open flue-heated bed used in New Jersey is 12 feet wide and 60 feet long. The walls commonly are built of concrete blocks, or of solid concrete. A firebox is built at one end, preferably at the end facing the cold winds, and deep enough to insure a good circulation of air under the bed. The inside of the firebox should be at least 3 feet wide, 6 feet long and 4 feet high if wood is to be used as fuel. The inside of the box is lined with fire brick surrounded by concrete.

For a bed 12 feet wide and 60 feet long two 6-inch flues are used. These flues are made of 6-inch round glazed tile pipe connected to the rear of the firebox as near the top as possible. The flues are placed under the ground to within a few feet of the farther end of the bed where they come to the surface under the bed. In order that there may be good draught, the flues should not be horizontal, but slope gradually upward from the firebox to the farther end where it is brought above the surface by an elbow. The soil covering is usually 15 to 16 inches deep near the firebox and 6 to 8 inches at the other end. A 30-foot bed may be heated by means of one 8-inch flue. In a bed of this length the air at the outlet is hot and it is best to protect the floor boards above the outlet with asbestos or with sheet metal. This protection is not necessary in a 60-foot bed.

Two chimneys are constructed for beds of the kind described, one in each corner at the firebox end. The height of these chimneys varies from 3 or 4 feet to 6 or 8 feet high, depending on the location. The smoke and warm air from the firebox go through the flues and pass out into the open space under the bed. They circulate under the bed and finally escape through the chimneys. The floor of the bed is made of boards placed on timbers laid across the bed.

For growing plants other than sweet potatoes, the open hotbed is not satisfactory. A hotbed of the type described can be covered with two rows of hotbed sash, with the upper end resting on a ridge in the center. The width should be less than 12 feet, however, in order to allow sufficient slope to the sash.

Hot-water Heated Hotbeds.—Hot water is the most satisfactory heat for hotbeds as the temperature can be controlled more easily than with any other method. It is more expensive to install than hot-air heat as used in the flue-heated beds. Since the installation of a hot-water heating system is more expensive than the other systems mentioned, care should be given in locating and constructing the beds. The hotbed frame should be made of concrete or other durable material.

Where greenhouses or other structures are heated by hot water, it is often possible to use the same boiler for heating the hotbeds. Nissley (1926) gives the following directions for installing a hot-water system for hotbeds:

> The boiler pit is located in close proximity to the beds and on the north side. It must be deep enough to insure good circulation of water, and so roomy that plenty of space is available to fire the boiler and to remove the ashes. It must be equipped with a good workable drain to carry away surplus water. The expansion tank is located over the boiler and is of good size. An oversized boiler is recommended as it will not require as much attention as will a boiler of just the required capacity.

In the more commonly used system the 2½ or 3-inch flow pipe leading away from the top of the boiler supplies the 2-inch header of the inside of the bed. This 2-inch header supplies the 1¼-inch flow pipes going to the end of the bed farthest away from the outer concrete wall. At the farther end of the bed is a 2-inch header pipe to which the flow pipes and the return pipes are connected. These flow pipes are spaced 12 inches apart from center to center, 1¼-inch pipe being used for both the flow and the return pipes through the bed. The return pipes in turn come back and empty into a 2-inch return header, where the returning water backs into the bottom of the boiler through a 2½- or 3-inch return pipe. The header, which is located at the farther end of the bed 6 inches from the concrete end, is equipped with two air stop-cocks to allow the air to escape when the system is being filled. There should be a 5- to 8-inch increase in elevation from the header at the farther end of the bed to the headers near the boiler. This is necessary in order to eliminate the air in the system and to create a better circulation of the water. The 1¼-inch pipes in the bed are placed 12 inches apart from center to center. A 6-foot bed would require 6 pipes, 3 flow and 3 return; an 8-foot bed would require 8 lines; and a 10-foot bed or a 12-foot bed would require 10 or 12 lines, respectively. Black pipe is recommended for use in the ground.

There are small hot-water heaters which are practicable for heating a relatively small hotbed.

Electric-heated Hotbeds.—During recent years there has developed considerable interest in heating hotbeds by electric current and several experiments have been undertaken to determine the practicability of this method of heating. Garver and Vincent (1927), Kable (1932), Currence (1932), Moses and Tavernetti (1934), Stout *et al.* (1936), and others have published results of studies of electric heating of hotbeds. Some of these investigators have given data on the cost of equipment and on the current consumed under different conditions. From these data one can estimate the probable cost of operating an electric hotbed under a given set of conditions. Garver and Vincent compared manure-heated with electric-heated hotbeds at Pullman, Wash., and found relatively little difference in cost between these two types when the cost of construction and equipment was distributed over three years. This calculation was based on the actual cost of materials used in construction, manure for heating at $12 per cord, and electric current at 3 cents per killowatt hour.

The most common type of heating by electricity is by passing current through specially constructed cable, consisting of electrically insulated resistance wire enclosed in a flexible metal sheath. The temperature in the bed can be controlled automatically by means of a thermostat.

The main advantages of the electric hotbed are as follows:

1. They are always ready for use.
2. They may be converted into cold frames by turning off the electricity.

3. They are easily manipulated and readily moved.
4. They can be used as long as may be necessary, whereas manure loses its heat in a few weeks.

The first cost of an electric hotbed is greater than for a manure hotbed and it requires some experience with electric apparatus to build and operate an electrically-heated bed. Where electricity is available at a low cost, electric hotbeds give promise of being practicable. Electric hotbeds are being used to a considerable extent in Norway and Sweden where electric current is cheap. Reports from these countries are favorable to the use of electricity for this purpose.

COLD FRAMES

Use of Cold Frames.—There are four general purposes for which cold frames are used: (1) for starting plants in the spring, (2) for hardening off plants which have been started in the hotbed or greenhouse, (3) for wintering hardy plants started in the fall, (4) for growing crops such as lettuce, radishes, beets, and parsley to maturity. In many sections, especially in the South, nearly all kinds of plants are started in cold frames but they are not so satisfactory as hotbeds for most crops where earliness is an important factor. If only a little protection is necessary, cold frames are satisfactory for starting plants. In the vicinity of Norfolk, Va., and elsewhere in the South, some crops such as cucumbers, melons, and beets are started in cold frames and when weather conditions permit the frames are removed and the crops receive field culture. In this case the crops are planted in rows about the same as for general field culture. In the North cold frames are used mainly for hardening off plants which have been started in hotbeds and greenhouses.

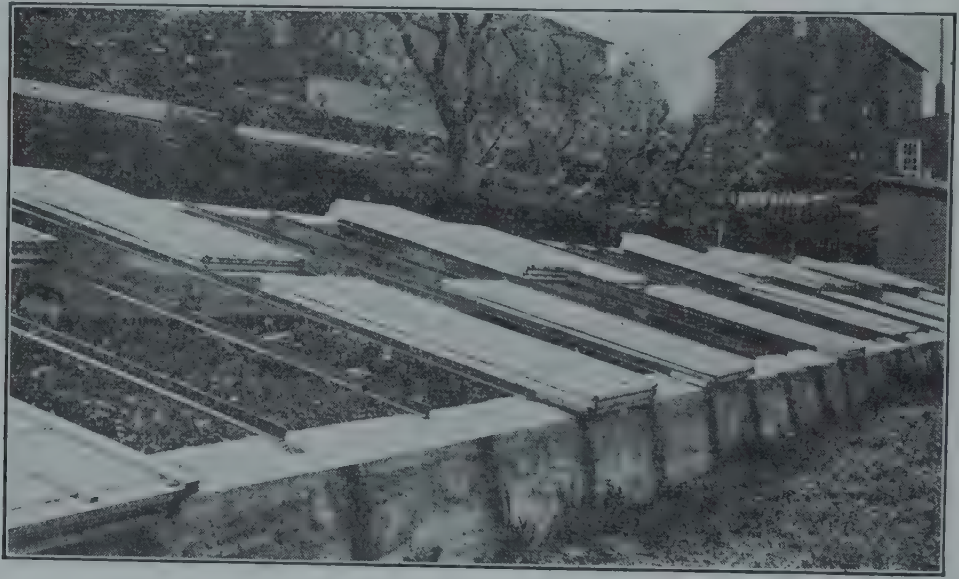
FIG. 4.—A good type of permanent cold frame.

Cold frames are constructed in very much the same way as hotbeds except that no pit is required. In fact the main difference between a hotbed and a cold frame is the absence of any form of heat in the latter, except that provided by the sun. Permanent cold frames are commonly made of concrete, Fig. 4, while temporary ones are made of boards.

Cold frames are covered with glass sash, canvas, or cloth. In the North glass is mostly used, while in the South canvas or cloth is commonly used. Where sash is used the frames are as a rule 6 feet wide, although frames 12 feet wide are not uncommon. When cloth is used the beds are very often 12 feet wide.

PLANT GROWING

Good plants are essential to success in vegetable growing. To have good plants one must get good seed and use judgment and care in sowing the seed, in the management of the seedbed, in transplanting the seedlings, and in hardening off the plants before they are planted in the open. Plant growing calls for skill and care. Any neglect may cause a serious loss due to delayed maturity or to a decrease in yield, or both. Perhaps no factor is more commonly neglected than the selection and the preparation of the soil for the plant bed.

Soil for the Plant Bed.—A good soil for plant growing is of good physical character, friable, retentive of moisture, and free of disease organisms, especially of the "damping off" fungi. It carries an abundance of nutrients for satisfactory growth. The demand for nutrients is heavy since a 3-inch layer of soil often must support a thick stand of sizable plants before time for setting in the field.

The base soil should be sandy loam well supplied with humus. A bluegrass sod grown on a good sandy loam soil makes an excellent base. An area may be specially prepared for a year by use of fertilizer and soil-improving crops. At least a year in advance of use a compost pile should be built, using one part of manure to two or three parts of soil according to need. If the soil is heavy some sand should be added, either to the compost pile or to the compost at the time it is used. A compost heap should be moist for rapid decomposition and should be turned once or twice for thorough mixing of the ingredients. Poorly blended soils often produce uneven plants.

Fine sifting is not necessary, but a coarse revolving screen, often homemade, is an excellent mixer. Special machines for soil shredding are on the market. The soil should be so stored in the fall that it will be available when needed regardless of the weather.

If the soil is contaminated with disease organisms it may be sterilized by means of formaldehyde, by steam, or by electricity.

Sowing Seed.—Moisture, oxygen, and congenial temperature are requisites of germination. In greenhouses and hotbeds moisture and a congenial temperature are artificially provided, but to maintain the proper moisture the soil must be of good texture. The soil for the seedbed should be light and friable, but not so light that it dries out quickly. A heavy soil, or one containing considerable clay, is not satisfactory because when the surface becomes dry it gets hard and cracks, and if kept wet it puddles and these conditions are not favorable for good germination and growth. A sandy-loam soil is most generally used for seedbeds, but muck is considered almost ideal for celery, lettuce, and some other crops.

The time for sowing seeds in greenhouses, hotbeds, or cold frames depends on the kind of crop and the subsequent treatment it is to receive before the plants are to be set in the field. If they are to be set directly from the seedbed less time is given than when they are to be transplanted once or twice. In general the length of time between seed sowing and setting the plants in the field varies from 3 or 4 weeks to 12 weeks. When the plants are not transplanted prior to setting in the field, 4 to 6 weeks are usually allowed between the sowing of the seed and setting the plants. A longer time is allowed in outdoor seedbeds than in greenhouses, hotbeds, or cold frames, since the growing conditions are less likely to be favorable in the former than in the latter. When only one transplanting is to be made and the usual spacing is given, the seed of most crops should not be planted more than 6 weeks prior to time for planting in the field. Many growers start plants too early for best results. When started too early, the plants are likely to become stunted or else allowed to get too tall and spindly. Early planting also increases the cost of growing the plants. Plant-growing requirements for specific crops are given under the discussion of individual crops.

Seeds are planted in flats or directly in the soil of the greenhouse bench, hotbed, or cold frame. The flat is filled with a good, friable soil which should be firmed to prevent too much settling. It is particularly important to firm the soil in the corners and along the edges. The firming of the soil is done with a board to leave the surface level and smooth. The surface of the soil should be below the top of the flat to prevent water running off.

Most vegetable seeds are sown in rows and covered with soil. When flats are used the rows are spaced about two inches apart, but in greenhouse benches and in hotbeds, the rows are usually 3 to 6 inches apart, the wider spacing being used when the seedlings are not to be pricked out. A convenient method of measuring and marking the rows to receive the seed is to use a stick about 2 inches wide, ¼ inch thick and of a length to fit the flat. The edge of the stick may be pressed into the soil to the depth desired. After all of the rows are made the seed is planted thinly and is covered by sifting fine soil over the rows and firming it lightly. When sowing seed direct to the soil of the hotbed, greenhouse, or frame, a rake-like marker is often used. After the seed is sown it is covered by hand by brushing it lightly back and forth over the row to fill the little furrow. There are small hand seeders which are used for sowing seeds in greenhouse benches and in hotbeds. This machine is pulled across the bed by the hand in much the same way as one would use a hand weeder. Small seeds are sometimes sown broadcast and covered very lightly with fine soil, or merely covered with a piece of cloth or burlap. The latter method is often used for celery and other small seed.

The depth of soil over the seed depends, to a considerable extent, on the size of seed and the kind of soil. Very small seeds should be covered lightly if at all. Cabbage seeds and others of similar size are covered to the depth of about ¼ inch, while beets are covered to the depth of ½ inch in light soil. In heavy soil, seeds should have less covering than in light soils.

Care of the Seedbed.—Very close attention must be given the seedbed if good results are to be obtained. Only by experience can one learn just how to care for the seedbed under the artificial conditions that prevail in greenhouses, hotbeds, and cold frames. The gardener wants good stocky plants ready at the required season, and to have them great care must be given to the temperature, moisture, ventilation, transplanting, and "hardening off." Things to avoid are: (1) chilling the plants, (2) overheating and lack of ventilation which make the plants soft, (3) overwatering, which makes the plants soft and very susceptible to "damping off," and (4) wilting of plants due to too much heat or too little water.

WATERING.—Caution should be exercised in watering the seedbed. Before the seedlings come through the surface there is danger of washing out the seed and puddling the soil. At this time the seedbed should be watered with a fine spray from a sprinkling can or with a fine rose on a garden hose. Water dashed on the seedbed through an ordinary hose nozzle or through a rose with large holes is likely to wash out the seed. The seedbed should never be allowed to dry out, nor should it be kept soaked, but sufficient water should be applied to wet all of the soil in the flat. Until the plants are well established the soil should be kept fairly moist but not wet. After the plants are well established the watering should be done thoroughly, but not too often. There is usually more danger of overwatering than underwatering. Keeping the surface wet after the plants are up is favorable to "damping off," hence it is best not to water often, but to soak the soil thoroughly and then withhold water until the plants show the need of it. Of course more water is required on a bright day than on a cloudy or rainy day because of greater evaporation and transpiration. In fact plants should not be watered on cloudy days unless absolutely necessary. Watering should be done early enough in the day to allow the foliage of the plants to dry off before night. It is best to do the watering in the morning, for if done during the middle of the day there is some danger of sunscald, and if done late in the afternoon the plants may not dry off before night. Watering reduces the temperature in the hotbed, and for this reason it should be done early enough to allow the bed to get warm before the sun goes down. Before the plants are to be taken up to set in the field the plant bed should be thoroughly soaked so as to have as much soil as possible adhere to the roots.

CONTROLLING TEMPERATURE.—In greenhouses and in steam- or hot-water-heated hotbeds the temperature is controlled by turning on and turning off the heat in some or all of the pipes and by regulating the ventilation. During bright days in spring it is often necessary to turn off all of the heat and ventilate thoroughly to keep the temperature down. The temperature that should be maintained depends on the kind of crop. Tomatoes, peppers, eggplants, cucumbers, and melons thrive best in a relatively high temperature, while cabbage, cauliflower, lettuce, celery, onions, and beets do best in a relatively low temperature. Slow, steady growth is preferable; therefore the temperature should not be high enough to make rapid, succulent growth nor low enough to check growth until time for hardening the plants.

Ventilation of greenhouses and frames where young plants are growing needs careful attention. Ventilation dries the air and aids in the control of the temperature. In greenhouses ventilation is obtained by opening the ventilators, while in frames the sashes are raised at one end or pulled down a short distance. The tendency is to ventilate too little rather than too much. As plants grow, more and more ventilation should be given until finally on bright warm days the sash may be removed. In ventilating during cold weather the wind should not be allowed to strike the plants. In greenhouses this is obviated by opening the ventilators on the side of the house opposite the direction of the wind. In frames the wind is prevented from striking the plants by raising the end of the sash on the side of the frame opposite the direction of the wind.

Transplanting.—Plants started in the greenhouse, hotbed, or cold frame are usually transplanted at least once, and sometimes twice or three times prior to being set in the field. The common practice is to sow seeds thickly in flats, or directly in the soil of the greenhouse, hotbed, or cold frame. When the first true leaves are fairly well developed the seedlings are usually transplanted or "pricked out" either into flats or into the soil of the greenhouse bed, hotbed, or cold frame. The soil should be loose and friable. The flat is filled with soil, which is firmed a little in the corners and along the sides. A leveling strip is used to remove the surface soil and to leave the surface level, then the soil is compacted lightly. Holes to receive the plants may be made with the finger, with a small dibble or with a spotting board, similar to the one shown in Fig. 5. The use of the spotting board is desirable in order to get the plants evenly spaced. For best results the soil should be moist, but not wet enough to stick to the pegs.

Seedlings are spaced 1 to 2 inches apart each way depending on the size of the plants and the length of time they are to remain in the box or bed. Sometimes plants are transplanted twice before being set in the field. As soon as they begin to crowd after the first transplanting they are taken up and transplanted again, spacing them farther apart. If the plants have been planted 2 by 2 inches the first time they may be spaced 3 by 3 or 4 by 4 inches at the second transplanting. Tomatoes and some other plants are often put in paper bands, veneer bands, flower pots, tin cans, or other containers at the second transplanting, one plant to each receptacle. The main advantage in using pots, or dirt bands, is that the roots are not disturbed when the plant is set in the field as all of the soil around the roots remains intact. Loomis (1924) has shown the advantage of pots over flats for the growing of tomato plants. With paper pots 4 inches square in 1922 there was a gain of 29.5 per cent in total yield, and 63.0 per cent in early yield as compared to flats. In 1923 the gain for large plants was 15.8 in total yield and 40.1 per cent in early yield, while for small plants the same year the gains are 17.7 and 27.0 per cent respectively. In transplanting, the soil should be pressed down around the roots, with care to see that the hole is closed at the bottom. The stems of young, succulent plants are sometimes injured by pressing with the fingers in transplanting. The pressure should be

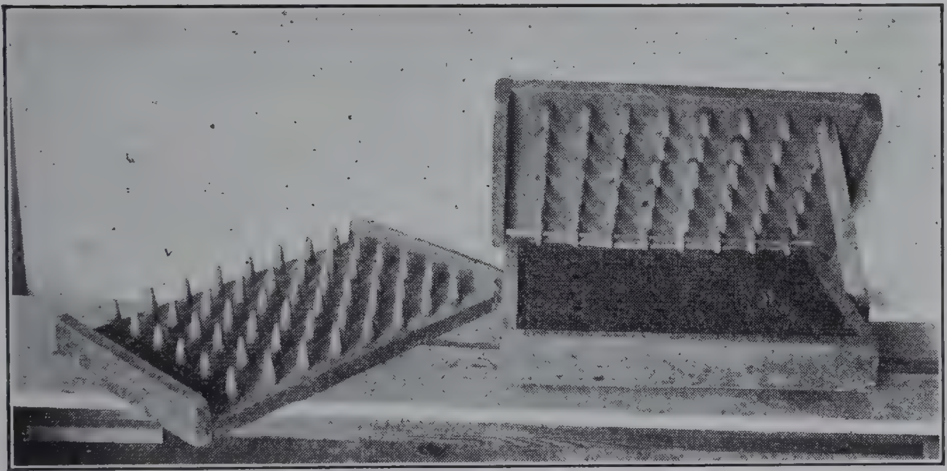

FIG. 5.—Spotting boards used in making holes to receive seedling plants.

exerted downward rather than against the plant. After each transplanting the plants should be watered thoroughly to settle the soil round the roots. When the plants are soft it is an advantage to shade them until they become established. Bright warm sunshine is likely to cause wilting since the roots cannot take up moisture as fast as it is transpired from the leaves.

Seeds of cucumbers, melons, Lima beans, and sweet corn are sometimes planted in pots or plant bands a few weeks before time for setting in the open. Several seeds are planted in each receptacle and the young plants thinned to the desired number either before or after planting in the field. In planting in the field all of the soil is kept around the roots so as to check the growth of the plant as little as possible.

ADVANTAGES AND DISADVANTAGES OF TRANSPLANTING.—The main advantages in transplanting plants prior to setting them in the field or garden are economy in the use of valuable space in the greenhouse, hotbed, or cold frame and economy in the care of slowly-developing seedlings. With expensive seed there is the additional advantage of saving of seed. If plants are not to be transplanted it is necessary to have the seedbed of sufficient size to allow the plants to grow for several weeks without crowding. This would mean utilizing more space than is needed for the first few weeks, and also adds to the labor and expense of caring for the seedbed. For example, several hundred cabbage seedlings can be started in a flat 12 by 18 inches in size, whereas when they are transplanted 2 by 2 inches apart the flat would hold only 48 plants. With other vegetable-crop plants similar economy in the use of seedbed space results from growing seedlings thickly and then transplanting them at the proper time.

Increase in root branching results from the transplanting of many plants. This is an advantage when the plants are grown in beds and must be taken up before they are transferred to the field. This is due to the fact that in taking up the plants from the seedbed some of the roots are broken and this results in greater root branching than is the case when the plants are allowed to grow in the seedbed. There are many more short branch roots on transplanted plants of those kinds which are readily transplanted, than on nontransplanted plants. This means that when the plants are taken up for setting in the field there is a larger absorbing surface in the block of soil around the roots of transplanted plants than in a similar block of soil taken up with nontransplanted plants. There is, however, no advantage in more than one transplanting. In fact, with some plants more than one transplanting results in excessive branching and a reduced spread. A slight increase in the number of branch roots is not accompanied by a decreased spread, but marked increase in branching results in considerable reduction in feeding area.

When pots or plant bands are used there is no advantage in transplanting, as far as the response of the plant is concerned, since practically all of the roots remain intact when the plants are set out. Results of experiments by Cranefield (1899) and Boyle (1913) indicate that transplanting is a disadvantage when pots or plant bands are used.

Many growers and others believe that transplanting results in a more stocky plant with a better root system and that this increases the yield and hastens maturity. Experimental evidence indicates that transplanting in itself generally does not increase the yield or hasten maturity, but that the increase in space and better conditions usually given do have this effect. In most of the earlier experiments the space factor was not eliminated and other factors also were involved, so that the advantages claimed were not due to the transplanting, but to more favorable environment for growth. In some cases the plants referred to as transplanted were not taken up and reset, but merely were shifted from one receptacle to another. These were compared with nontransplanted plants grown in beds or in flats.

The main disadvantages of transplanting are the extra labor required and the check in growth due to taking up and resetting the plants. The extra labor involved often is offset by the economy in the use of valuable greenhouse space for the seedbed and the saving of labor in caring for the plants. All plants are checked in growth by transplanting, but with those that are easily transplanted, this check may be offset by the increase in root branching. Even with such plants as cabbage and tomatoes transplanting when the plants are large usually results in delayed maturity and often in reduced yield. With plants poorly adapted to transplanting, such as corn, cucumbers, melons, and beans, the check in growth is very marked and results in serious reduction in yield unless the transplanting is done while the plants are small. A second transplanting of these plants is usually very injurious. It is doubtful if more than one transplanting of any plants is justified as far as crop yields are concerned. It may be desirable from the standpoint of economy in the use of valuable space.

Cranefield (1899), working in Wisconsin, showed that transplanting resulted in reduced yields. He planted seeds in pots and the plants given the transplanting treatment were taken up and reset in the same place, while the "check" plants were not disturbed. With all crops, cabbage, cauliflower, kale, lettuce, and tomatoes the yield was reduced. Those transplanted twice produced a lower yield than those transplanted only once. Loomis (1925) in an elaborate series of experiments at Ithaca, N. Y., with several vegetable crops, found that transplanting always resulted in a check in growth, the check being proportional to the size of the plant at the time it was reset. This check in growth did not always result in a reduced yield, because differences due to transplanting in the greenhouse frequently were obscured by the shift to the field, or by hardening prior to the shift. The effect generally was more to retard development than to decrease the yield. Loomis concludes as follows:

> While there are isolated instances of crops which appear to have made a thriftier growth after an early transplanting, these instances will seldom bear statistical analysis, and the conclusion that transplanting is a harmful but frequently necessary operation seems to be required. On the other hand, the field data do not justify a large expense to avoid early transplantings, since the only shift which has consistently affected either earliness or total yield in cabbage and tomatoes is the final one to the field.

DIFFERENCE IN RESPONSE TO TRANSPLANTING.—It is well known that some plants are more injured by transplanting than are others. In fact, it is believed by many that some plants will not withstand the process, but the evidence from Loomis' experiments indicates that any of the common vegetable plants may be transplanted satisfactorily during the early stage of growth. With some kinds of plants, such as corn, beans, and the cucurbits, there is only a short period when they are not seriously injured by being taken up and reset. This is the reason that these plants are usually grown in pots or plant bands when they are started indoors. Even with those crops which commonly are transplanted, such as tomatoes and cabbages, the check in growth is considerable if the transplanting is done when the plants are large.

Results of experiments conducted by Loomis clearly established a correlation between the ease of transplanting and rate of new root formation. Plants which are rather easily transplanted showed a slow rate of root replacement, but also a slow rate of top growth. Plants seriously injured by transplanting normally have a rapid rate of top growth and slow root replacement. Loomis concluded "that root replacement appears to be the largest single factor concerned in transplanting." Figure 6 illustrates the difference in root replacement of cabbage and corn plants. Eight days after being transplanted the transplanted cabbage plant had a much greater absorbing surface, due to root branching, than did the check plant. The transplanted corn plant, on the other hand, had not branched at all and the total absorbing surface was very much less than that of the plant which had not been transplanted. With increasing age the rate of root replacement decreases with most, if not all, vegetable plants.

The immediate effect of transplanting is a slowing down or stopping of the growth of the plant for a period; this seems to vary directly with the quantity and duration of the reduction of the water supply. While various factors, both environmental and internal, affect recovery from transplanting, they all act through their final effects on the water supply.

This is only slightly influenced by the tops. The roots are the most important factor involved in resistance to, and recovery from, transplanting. Loomis suggests that there are three factors concerned: (1) the proportion of the root system retained in transplanting, which depends on the size of the plant and the character of root branching, (2) the effectiveness of the retained roots in absorbing water during the first few days after transplanting, an effect presumably correlated with the amount of suberization in the older roots, and (3) the rate of new root formation, which depends on the kind of plant, its age, and possibly on the stored food. There is evidence that the roots of some plants which are difficult to transplant are suberized or cutinized at an early age. Deposition of suberin or cutin in the endodermis, or in the periderm layer would hinder water absorption and this would have a marked effect on the recovery of the plant following transplanting. Loomis found that branch formation in shortened roots was inversely proportional to the extent to which suberization had progressed.

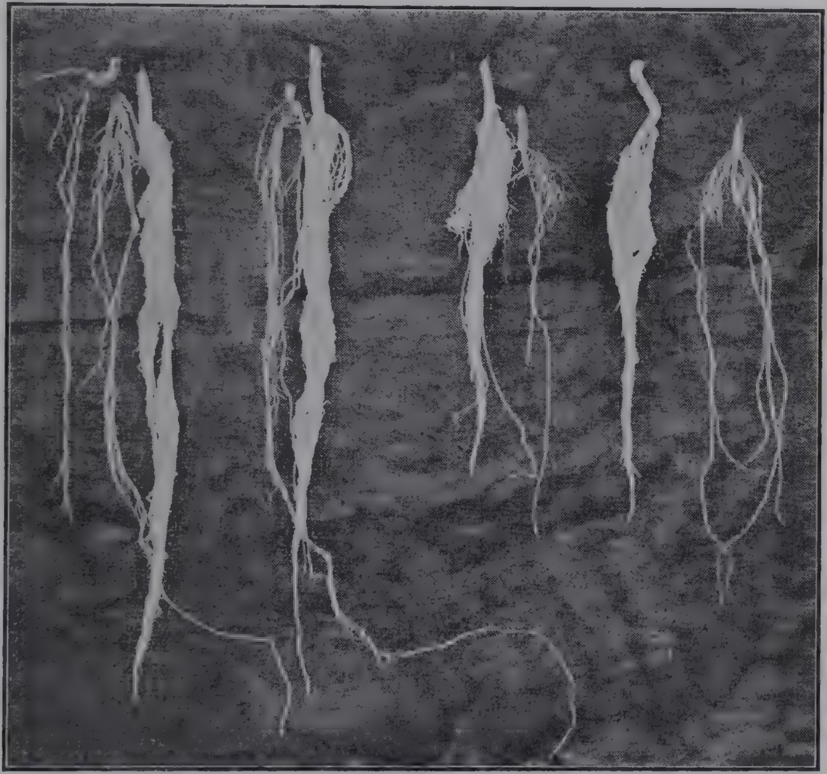

Fig. 6.—Root systems of 8-weeks-old cabbage plants (four on the left), and of 2-weeks-old corn plants (four on the right), showing effects of transplanting on the root system. The plant on the left of each set of two is the non-transplanted plant and the one on the right is the transplanted one 8 days after transplanting. (*Cornell Univ. Agr. Exp. Sta.*)

Containers for Plant Growing.—Various kinds of containers are used for growing plants, one plant to a container. Clay pots, paper bands, paper pots, peat pots, and wood veneer bands are the most common.

Containers made of carbonaceous materials such as wood, paper, or peat frequently give unsatisfactory results. Studies by Knott and Jeffries (1929), Haber (1931), Jones (1931), and Youden and Zimmerman (1936) indicate that the poor growth of plants in these containers is due to deficiency of nitrates. The carbonaceous material of these containers supplies energy food for organisms that cause decomposition of the material itself. These organisms also consume nitrates and thus compete with the crop plants for the available nitrates in the soil. By supplying extra nitrates to the potting soil and by adding nitrogenous fertilizer as need is evidenced by the plant, the difficulty is overcome. New clay pots take up nitrates from the soil solution and, for this reason, plants grown in them frequently make slower growth than plants grown in pots that have been used. Soaking new pots in a solution of nitrate of soda, or applying nitrogenous fertilizer when needed, will supply the deficiency.

One advantage of using pots and plant bands is that the roots are not injured or disturbed when the plant is set in the field as the ball of soil is moved with the plant. In the case of peat pots, the pot is set in the soil with the plant and the roots grow through the walls of the container and enter the soil.

Blocking Plants.—A method of growing tomato and other plants, known as blocking, is practiced in some parts of New Jersey. The blocking is done about 10 days before the plants are to go to the field, and consists of cutting the soil and compost into blocks with a blocking hoe. The shank of a wide-bladed hoe is straightened out to make the blocking hoe, or a cutting tool made from a crosscut saw is used for the purpose.

The bed is specially prepared for the plants before they are "spotted out," by spreading 2 or 3 inches of compost on the spotting bed, then before the compost has had a chance to get dry sandy-loam soil is spread on it tc the depth of 2 or 3 inches. When the material settles it is of the desired thickness for tomatoes and eggplants.

In blocking, the operator stands on a plank over the bed and cuts between plants so that each plant has a block of soil at least 3 by 3 inches, and as deep as the soil and compost. The cutting severs the large lateral roots and new branch roots form. The cutting of the roots checks growth somewhat and the check results in the development of more feeder roots.

Hardening Plants.—The term "hardening" or "hardening off" is applied to any treatment that results in a firming or hardening of the tissues of the plants, thus enabling them better to withstand unfavorable environmental conditions. Many persons speak of hardening only in connection with the processes that enable plants to withstand frost injury, but it is as important to harden them so that they will withstand insect injury, whipping, hot drying winds, or other unfavorable conditions. All experienced gardeners know that soft, tender plants are injured by unfavorable soil, or atmospheric conditions, and make an effort to prevent this injury by subjecting them to some hardening treatment.

Any treatment that materially checks growth increases hardiness. With plants that possess potential hardiness, as cabbage and related crops, hardiness increases in proportion as growth is checked. With tender plants like tomatoes, peppers, eggplants, and the cucurbits, checking growth results in only slight resistance to cold.

The treatments commonly used to harden plants are exposing them to relatively low temperature for a week or more and allowing the soil of the plant bed to become dry, or a combination of these two. Exposing plants to relatively low temperature is perhaps the most common method employed and this is usually accompanied by withholding water. Exposure to low temperature is done by reducing the heat and increasing the ventilation in greenhouses and hotbeds, or by removing the plants to a cold frame. Since any treatment that checks growth results in hardening, it is evident that low temperature is not essential; therefore, removing plants to cold frames is an unnecessary expense unless the greenhouse or hotbed is needed for other plants. In other words, hardening can be accomplished as well in the greenhouse or hotbed by withholding water as by exposing them to low temperature in the cold frame. It is easier to control the water supply than to control the temperature. With some plants, notably celery and cabbage, and probably others, exposing them to relatively low temperature (40° to 50°F.) for 2 weeks may result in serious loss due to premature development of the seed stalk. This subject is discussed in considerable detail under celery in Chap. XVIII.

According to Rosa (1921) hardening is accompanied by (1) slowing up of the rate of growth, (2) thickening of the cuticle, (3) increasing the waxy covering on the leaves, (4) increasing the percentage of dry matter, (5) decreasing the transpiration per unit area of leaf, (6) increasing the quantity of hydrophilous colloids, especially pentosans, (7) decreasing the percentage of freezable water, (8) increasing the percentage of reducing and total sugars, (9) decreasing the starch, and (10) development of a pink color, especially in the stems, petioles, and leaf veins. The leaves of hardened plants are of a deeper green color and smaller in size than those of nonhardened plants of the same age. Harvey (1918) suggested that the principal effect of hardening cabbage plants is a change in the constituents of the protoplasm which prevent their precipitation as a result of the physical changes incident to freezing. The proteins are changed to forms which are less easily precipitated. This is indicated by an increase in the amino-acid content of the cabbage on hardening.

The factors that produce protein precipitation on freezing of a plant juice, Harvey believes to be principally the increase in hydrogen-ion concentration, and the increase in salt concentration. The latter factor he holds is insufficient to cause precipitation except under conditions of changed acidity.

Loomis has shown that immediately following transplanting the transpiration rate is greater in hardened plants than in nonhardened ones. This is due to a more prompt regeneration of the root system of hardened plants which, in turn, results from the accumulation of carbohydrates during the hardening treatment.

It seems evident that the most important changes occurring during hardening are those which increase the water-retaining power of the cell. The decrease in water and the increase in the colloid content are important factors in increasing the water-holding power. Harvey believes that the thickening of the waxy covering on the leaves of cabbage is important in protecting plants against freezing. Undercooling of the cell solution is of considerable importance and Harvey found that those plants which have the most bloom on the surface of the leaf are the most resistant to the formation of ice within the tissue.

Hardening should be gradual in order to prevent a severe check to growth, or the possible killing of the plant. It is better to maintain a moderate rate of growth throughout the plant-growing period than to have rapid growth up to the time of hardening and then to check it suddenly. Many growers overharden their plants and this results in delayed growth after the plants are set in the field. Crist (1928) found that severe hardening of tomato plants decreased the yield of early fruit in the greenhouse, and, it seems probable that this would be true of tomatoes grown in the open. Forcing plants after they had been hardened did not overcome the check suffered in the hardening treatment.

Commercial Plant Growing in the South.—The growing of plants for sale is of considerable importance in certain sections of the South. The most important areas are the Rio Grande Valley of Texas and the Tifton-Valdosta area in Georgia; but areas in South Carolina, Virginia, Louisiana, and Arkansas grow plants on a fairly large scale. Hundreds of millions of these plants, including sweet potatoes, tomatoes, cabbages, onions, peppers, eggplants, cauliflower, and others, are shipped to the Northern states and to other sections of the South. Since these plants are grown, in most cases, in the field and are not transplanted prior to field setting, the cost of production is very low as compared with plants grown in greenhouses or hotbeds in the North.

Experiments comparing Southern, field-grown plants with home-grown plants in the North have yielded conflicting results. Hartman and Stair (1937) reported results of experiments conducted at Greenwood, Ind., for two years and at Lafayette, Ind., for one year in which Southern-grown tomato plants compared favorably with plants grown locally by several of the usual methods. At Greenwood in 1936, the difference in yield between Georgia-grown plants and plants grown locally by three different methods (hotbed, cold frame, and a combination of hotbed and cold frame) was not significant; in 1937 the difference was significant and was in favor of the Southern-grown plants. At Lafayette in 1937 several lots of Southern, field-grown plants were compared with field-grown plants produced in southern Indiana and southern Illinois and with greenhouse and cold-frame plants grown locally. Some lots of the Southern plants produced higher yields and other lots produced lower yields than plants grown locally in greenhouse and cold frame. Sayre (1938 and 1939) reported results of experiments carried on at Geneva, N. Y., in 1937 and 1938. In 1937 plants grown in Georgia produced a considerably lower yield than plants grown at Geneva by the usual methods but Virginia-grown plants, planted soon after arrival, compared favorably with locally grown plants. In 1938, however, the plants grown in Virginia and in Georgia produced only about half as large a yield as plants grown at Geneva by approved methods.

Hartman and Stair suggest that the condition of the plants when set is more important than the locality in which they are produced. The soil and weather conditions at the time of setting and immediately thereafter also are important. Soft, succulent plants are likely to heat in transit and to reach their destination in such poor condition that many will not survive unfavorable conditions, and those that do will start growth slowly. Plants that are too hard and woody will grow slowly at first and fruit setting will be delayed. Well-hardened, freshly pulled plants are more likely to withstand unfavorable conditions such as dry soil and hot, dry weather at planting time than are plants that are in transit a day or two after being pulled.

The danger of introducing disease into a region should be considered in buying plants from a distance. While many plant growers are careful in all of their operations and some of the states furnish good inspection service, the danger of introducing a disease into another area is not eliminated completely.

CHAPTER IX

PLANTING VEGETABLE CROPS IN THE OPEN

The time and method of planting seeds and plants of a particular species in the open determine to a considerable extent the success or failure of the crop. Even with good seeds or good plants satisfactory and profitable crops will not be produced unless the planting is done at the right time and in a proper manner. Attention must be given to the preparation of the soil for the seedbed, to the depth of planting, to the rate of planting, and to various other factors such as thinning and watering to insure a satisfactory stand of plants. Planting both seeds and plants in the open is considered in this chapter.

Time of Planting.—No definite date can be given for planting vegetable seeds and plants, because climatic conditions vary widely within relatively small areas due to differences in elevation, proximity to large bodies of water, etc. The time of planting should be determined with reference to the soil and weather conditions, to the kind of crop, and to the time the produce is desired. Where earliness is an important factor most commercial and home gardeners make their first planting as early in the growing season as weather and soil conditions are satisfactory for the crop or crops to be grown. In sections of the South, where cool-season crops are grown for marketing during the early part of the winter, it is the practice to plant the seed as early in the autumn as weather conditions will allow. In this case planting is delayed until the weather gets cool. In most other sections of the South and in the North the first planting usually is made as early in the winter or spring as it is safe, that is, as soon as the danger from cold injury is past. Vegetable crops may be grouped into three classes with respect to cold resistance: (1) hardy or those that will withstand hard frosts, (2) half-hardy or those that will withstand light frosts and the seeds of which will germinate at low temperatures, (3) tender or those unable to withstand any frost and the seeds of which will not germinate in cold soil. The hardy group includes kale, spinach, turnip, mustard, onion, and peas; seeds of these may be planted as soon as the soil can be prepared in the spring. Cabbage plants, which have been well hardened, may also be transplanted into the open at this time. Seeds and plants of the half-hardy group may be planted 2 or 3 weeks before settled weather, or before the danger of killing frost is over. Beets, carrots, parsnips, celery (seed and hardened plants), lettuce, and chard belong to this group. The third group includes beans, sweet corn, Lima beans, squash, pumpkins, melons, cucumbers, okra, tomato plants, eggplant, and pepper plants. Sweet corn and beans will withstand more cold than the others in this group and are often planted before danger of frost is over. It pays to take some chances on most crops which are grown from seed planted directly in the field, since the cost of seed and labor of planting are usually not large items and earliness means much in marketing the crop.

When more than one planting is made of any crop the second and later plantings should be timed so as to have a continuous harvest for the period desired. This is especially important for the home gardener and for the market gardener who attempts to supply special customers. In timing various plantings, it should be borne in mind that the temperature and other ecological factors have a marked effect on the length of time required from planting to harvest. For example, Culpepper and Magoon (1926) and Appleman (1923) have shown that the higher the temperature, the shorter the time required to bring sweet corn to any definite stage of maturity. Culpepper and Magoon found that the number of days from planting to silking in sweet corn at Washington, D. C., varied from 63 to 92 days for the Stowell's Evergreen variety. Appleman showed that the rate of ripening of sweet corn is directly proportional to the temperature. This is discussed in Chap. XXVII.

Depth of Planting Seeds.—No definite rules can be given regarding the depth to plant seeds of various kinds. The size of the seed, the kind of soil, and the amount of moisture in the soil should be considered. Large seeds are planted deeper than small seeds, although it does not follow that the largest seeds should be planted the deepest. Kidney beans and Lima beans are not usually planted as deep as peas, because unlike the pea the young bean plant pushes the cotyledons up through the soil and if the covering is too deep they may be broken off and the plant thereby injured. Small seeds, such as celery, are often merely pressed into the soil or covered with burlap or other similar material. On light soils such as fine sand or sandy loams, seeds are planted to a greater depth than on heavy soils. The more moisture there is present in the soil the less need there is for deep planting and for this reason seeds are usually given a relatively light covering in the spring. The same kind of seeds planted in late summer require greater covering because the surface layer of soil is usually drier and it is necessary to place the seed at a greater depth to obtain sufficient moisture to insure germination and to bring the plant to the surface.

Marking Rows.—Straight rows and even spacing are important in growing vegetables on a commercial scale. Straight rows add to the appearance and also make cultivation easier and more rapid. In spraying celery and other crops with a power sprayer straight rows and uniform spacing are essential to good work. The spray nozzles are usually set certain distances apart, and, while they can be changed, it requires much time to adjust them for each set of rows to be sprayed.

Straight rows can be secured by using either a line, or markers of various kinds. When drills are used for planting seeds a line should be used for the first row and the marker attachment used for the remainder. The operator needs to take considerable pains to keep the rows straight when using the marker on the seed drill, or when marking the rows with a hand marker. The most careful and painstaking men should be used for marking out the land and sowing seeds with a drill.

Methods of Planting.—Most commercial gardeners plant seeds with machine planters of some kind. Machines do the work much better and more rapidly than is possible by hand sowing. The common seed drills open the furrow, drop the seeds, cover them, and pack the soil at one operation. These drills can be regulated to sow at various rates and at the depth desired. By regulating the rate of seed-sowing, thinning can be reduced to the minimum. There are several makes of seed drills on the market and all of them are satisfactory when properly used.

Sowing seed by hand is commonly practiced in home gardens, as too small quantity of any one kind of seed is used to justify the expense of a seed drill. It would be necessary to adjust the drill to the different kinds of seeds and the time required to do this would often be enough to do the planting by hand. A garden line or marker should be used when planting is to be done by hand in order to have straight rows. The furrow for small seeds may be made with the rake or hoe handle, using the same kind of a motion one uses in sweeping. For large seeds the furrow may be made with the corner of an ordinary hoe, with a heart-shaped hoe, with the plow attachment, or with one of the cultivator teeth of a wheel hoe. The seeds should be distributed uniformly in the furrow. Small seeds such as radish, turnip, lettuce, etc., may be sown direct from the seed packet or from an envelope with the end cut open, by moving it slowly over the row and tapping it lightly with the finger. The seeds should be covered immediately to prevent loss of moisture from the soil. After the seeds are covered, the soil, if dry, should be firmed by trampling or by tamping with the back of the hoe. This is especially important when the soil is dry as it brings the seed into close contact with the soil particles. The seed drill has a broad wheel that packs the soil over the seeds.

Rate of Planting.—Among the points to be taken into consideration in regard to the quantity of seed to plant are: (1) the viability of the seed, (2) the time of planting, (3) the condition of the soil, (4) the size and vigor of the young plants, and (5) the possible ravages of insects.

Seeds of low viability should be planted more thickly than those having a high percentage of germination. In order to determine the rate of seeding a germination test should be made in advance. If the percentage of germination is low, or if the sprout is weak the seed should not be planted, for a poor stand of weak plants would result.

Seeds planted when the soil and weather conditions are unfavorable to quick germination should be planted at a heavier rate than when the conditions are favorable. In early spring when the soil is cold, and in late summer when the soil is very dry and the weather hot, the rate of seeding should be heavier than when the temperature and moisture are favorable. The longer the time required for germination of any given kind of seed the heavier should be the rate of planting.

Seeds that produce delicate weak plants, such as carrots and parsnips, should be planted quite thickly to insure a good stand. Any excess of plants may be removed to prevent crowding.

In planting seeds of melons and cucumbers it is a common practice to plant freely in order to have several times as many plants as are needed. In most regions it is expected that the cucumber beetle will seriously injure, or even kill, many of the plants. Unless large numbers are started the chances are against saving enough for a good stand of strong plants. After the beetles have disappeared the plants may be thinned to the desired distance apart.

Thinning.—This is an important operation when seeds are planted where the crop is to mature for more plants usually come up than are needed, and, unless some are removed, injury by crowding will result. Thinning may be made a process of selection. The weakest plants should be discarded and the strongest left to grow. By thinning, a uniform stand is secured, but as this is a tedious and expensive operation gardeners try to avoid it as much as possible by planting the proper quantity of seed and distributing it evenly. There is a tendency among gardeners to delay thinning too long and this results in the plants that are to be left being relatively weak. Thinning should be done as soon as there is reasonable assurance that the plants left will not be killed by unfavorable weather conditions, or destroyed by insects that are injurious during the early stages of the plants' growth.

Transplanting.—Success in transplanting plants to the field or garden is dependent on good plants, good condition of the soil, and doing the work in the proper manner. The plants should be well grown, stocky, and well hardened to withstand the changed conditions. Slender, unusually soft or succulent plants do not withstand unfavorable soil and weather conditions as well as hardened plants. It is well known that hardened plants will withstand a lower temperature than plants not hardened, but it is not so well known that hardened plants also suffer less from dry, or hot weather.

The soil should be thoroughly prepared prior to transplanting. It is very difficult to set plants properly in hard, lumpy soil and plants set under these conditions are likely to be seriously checked in growth, or to become weak and die. Contact between the roots and soil is important because the roots cannot take up moisture unless they are in close contact with fine, loose soil. For the same reason it is essential that the soil be well firmed around the roots.

Some authorities recommend removing part of the foliage when the plants are set in the field, but it is doubtful if this is a desirable practice. While transpiration may be somewhat reduced by removing some of the leaves, the direct water loss from the injured surface may be greater than would be the loss by transpiration from the full-leaf area. Furthermore, the leaves carry on photosynthesis and reducing the leaf area is likely to reduce it, and, thereby, result in a lower supply of carbohydrates. The development of new roots is dependent on the carbohydrate supply and the ability of the plant to get water is limited by the growth of new roots, especially when the plants have not been transplanted previously.

The best time to set plants is just before, or just after a rain, especially if the weather is cloudy. Cool, cloudy weather is desirable because evaporation and transpiration are less under these conditions than in hot, dry weather. When it is necessary to transplant in hot, dry weather it is desirable to do the work in the late afternoon if possible in order that the plants may have time during the night to recuperate from the shock. However, with soil in good condition, plants that have been previously transplanted and well hardened can be set even during hot, dry weather without much wilting if they are taken up with a block of earth around the roots. Plants that have not been transplanted previously and are pulled from the seedbed without any soil adhering to the roots should be watered when the soil is very dry.

Plants are set by hand or by machines of various kinds. When setting by hand, various methods are used. For plants that have been transplanted prior to field planting, it is usually the custom to take them up with considerable soil around the roots, and in setting them a furrow is made with a small plow, or a hole large enough to take in the block or ball of soil is dug with a trowel, shovel, or spade. For large plants like tomatoes a one-horse turn plow may be used to good advantage for opening the furrow. The plants are set in the furrow and earth is packed around each with the hand and the remainder of the furrow is filled with a cultivator. The plow attachment of a hand cultivator, such as the Planet Junior, is valuable for opening furrows for cabbage, lettuce, celery, and similar plants which have been transplanted previously. The depth of the furrow can be regulated to suit the size of the plants. The best tool for making a hole for transplanting plants which are taken direct from the seedbed is the dibble. This tool makes a hole without removing the soil. The dibble is held in one hand and the plant in the other and after the hole is made a plant is inserted and then both hands are used to firm the soil around the roots, or the dibble may be used to press the soil against the plant. Care should be taken to see that the soil is firmed around the roots and that no space is left unfilled at the bottom of the hole. The trowel and spade are also used in setting plants either in the same manner as the dibble, or in digging holes for receiving the plants. There are small hand planters on the market, similar to the one shown in Fig. 7, which work very satisfactorily in good soil. A small tank on the side for water may be used if desired. By tripping the lever at the top a small quantity of water is applied around the roots of the plant, but this method of watering is practicable only on a small scale.

Large-scale planting of cabbage, sweet potato, tomato, and similar plants is often done by means of a transplanting machine. These machines do the work better and more rapidly than is commonly done by hand. These machines open the furrow, apply water, and firm the soil around the roots at one operation. Three persons and two horses or a tractor are necessary to operate this type of transplanter. One man drives and two men, or two careful boys, alternate in placing the plants in the furrow at the proper distances. Shoes close the furrow and press the soil against the roots and stem. The water is applied from the barrel through a hose that ends just in front of the shoes of the transplanter. Transplanting machines are not used to very good advantage in setting large plants which have soil around the roots as is usually the case with transplanted ones; therefore such plants are generally set by hand.

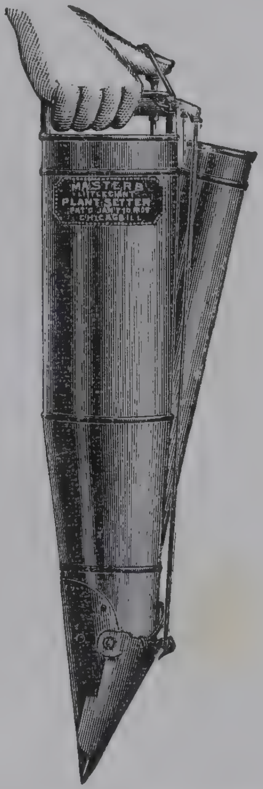

FIG. 7.—A small hand planter used for setting plants in the garden or field. (*Courtesy of Master's Planter Co.*)

Plants should be set slightly deeper than they were in the seedbed. It is an advantage to set long slender plants quite deep as this will keep them from being whipped by the wind, and, with some plants as the tomato, roots will grow from the stem below the surface of the soil. Care must be taken not to set celery and lettuce plants so deep that the crown will be buried.

Watering.—A plant set in very dry soil should be watered unless there is a block or ball of moist soil around the roots. The water should be applied around the roots and the wet soil covered with dry earth to prevent baking. In hand planting a little soil is usually packed around the roots and then the water is poured into the depression. After the water disappears the hole is filled with dry soil. The transplanting machine applies the water about the roots and in such small quantities that the surface of the soil is not puddled.

When watering is not practicable the roots of the plant are often puddled prior to setting. This is done by dipping the roots into a thin paste made with clay in water. Puddling prevents drying of the roots and also causes the soil particles to adhere to them when planted. The mud paste should not be allowed to dry on the roots as this would cause injury by preventing the moist soil from coming into contact with them. The puddling should be done just before planting or else the puddled plants covered with moist burlap, moist moss, straw, or other material to prevent evaporation of moisture in the paste. Puddling requires much less labor than watering the plants and gives satisfactory results when properly done. When plants are watered after being planted it is desirable to cover the moist soil with a little loose, dry earth to prevent rapid drying and consequent baking and cracking.

Number of Plants per Acre.—The number of plants required to plant an acre of ground at various spacings can be determined by multiplying the distance in feet between plants in the row by the distance in feet between the rows and dividing the product into 43,560, the number of

TABLE X.—NUMBER OF PLANTS PER ACRE AT DIFFERENT SPACINGS

Distance between plants in row, feet	Distance between rows, feet	Number of plants an acre	Distance between plants in row, feet	Distance between rows, feet	Number of plants an acre
0.5	1	87,120	1.25	2	17,420
0.5	1.5	58,000	1.25	3	11,600
0.5	2	43,560	1.5	2.5	11,600
0.5	2.5	34,850	1.5	3	9,680
0.5	3	29,000	2	2.5	8,700
0.5	3.5	24,900	2	3	7,260
1	1	43,560	2	3.5	6,220
1	1.5	29,000	2	4	5,445
1	2	21,780	3	3	4,840
1	2.5	17,420	3	4	3,630
1	3	14,520	3	5	2,900
1	3.5	12,450	4	4	2,720
1	4	10,890	4	5	2,180

square feet in an acre. The approximate number of plants required to set an acre of land at various spacings is given in Table X.

Use of Plant Protectors.—Various kinds of protectors have been used to protect individual plants and hills of plants or seeds in the field. The claim is made that by the use of protectors maturity is hastened due to increasing the temperature and protection against light frosts. Protectors also protect the plants from whipping by winds and heavy, dashing rains.

In France, bell jars are used for forcing plants in the field, but these have never come into use in the United States. A type of box covered with a pane of glass has been used to some extent by market gardeners for starting cucumber, melon, and other warm-season crops planted in hills. This type of box is made with a sloping top and a pane of glass is placed on top and held in place by a stone, or still better, the glass is slid into grooves cut into the top of the side boards. This makes a miniature cold frame.

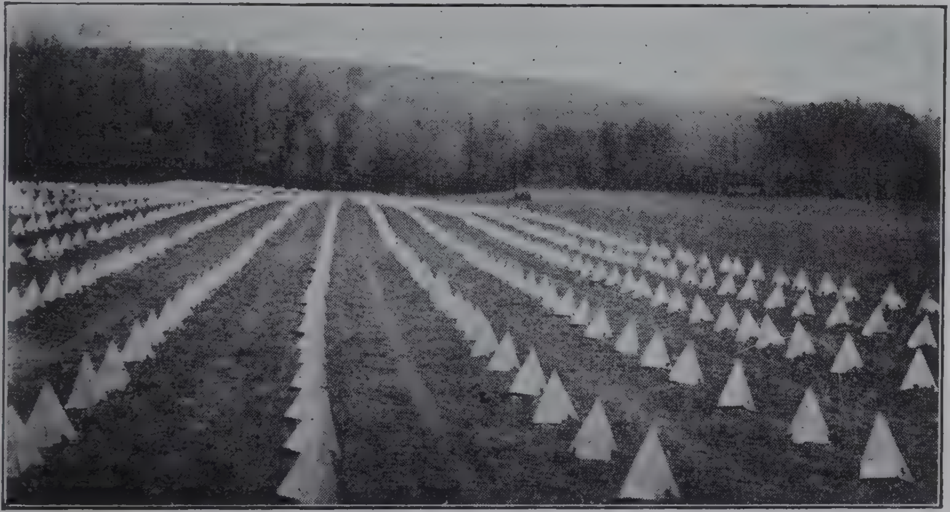

Fig. 8.—Paper plant protectors placed over tomato plants to protect them from frost injury. The plants are uncovered in mild weather. (*Cornell Univ. Agr. Exp. Sta.*)

Various kinds of paper protectors are in use in the United States in starting warm-season crops in the field. Such devices are used on a very large scale in the Imperial Valley of California for muskmelon (cantaloupe) and other tender plants. They are also used by thousands of growers in other sections of the country, especially in the North, for protecting tender plants that are started early.

Some of the protectors are factory made and are ready for use, and others come in sheets and require special forms to shape the paper. Glassine paper and oiled and waxed papers of various kinds are used in making plant protectors and these are superior to untreated paper. Paper protectors, such as are shown in Fig. 8, provide some heat and protect plants against light frosts and chilling winds as well as against wind injury by whipping and blowing sand and soil particles. They aid in preventing injury by some insects during the early stages of growth of the plant. On the other hand, the paper protectors reduce the intensity of the light reaching the plants and when this reduction is marked, growth is not normal. Hibbard (1925 and 1926) presented data on the effect of various materials on light intensity. Using figures representing the light intensities in the greenhouse as 100, the following descending order of light intensities was obtained: celluloid 91; glassine 81; light parchment 71; heavy parchment 71; oiled paper 64; medium parchment 61; and brown wrapping paper 23. Under another set of conditions out of doors the following figures were obtained: uncovered 100; cellulose 93; glassine 92; medium parchment 83; light parchment 80; oiled or waxed paper 76.

Results of studies by Ware (1936) in Arkansas, covering a period of three years, indicate that good plant protectors hastened germination and early growth and increased early and total yield of muskmelons.

Careful attention must be given to the plants under protectors to provide ventilation and to prevent too soft succulent growth under some conditions. Thompson (1929) has pointed out that protectors might be a disadvantage in a season when the weather is mild for some time and then a frost occurs. Under such conditions the protected plants are more likely to be injured or killed by frost than those that have been growing in the open and are more hardened. Unless some ventilation is provided moisture accumulates in drops and, on freezing, results in injuring or killing the portion of the plant in contact with the ice crystals. To get rid of excess moisture a 1-inch slit in the paper cones may be made on one side, preferably on the side away from the prevailing wind. This slit is lengthened as the plant grows and eventually the paper is pulled apart.

While many growers have used paper plant protectors with success and profit, there are conditions under which the protectors are of no advantage and may be actually injurious. On the average, however, the protectors do shield the plants and hasten maturity if careful attention is given the plants while the protectors are in use.

CHAPTER X

CULTIVATION

Cultivation is a well established practice and its benefits are well known. There is, however, a great deal of misconception as to the reasons for the benefits derived from the practice. Many theories have been advanced and many experiments have been conducted to determine the reasons for the beneficial effects of cultivation of crop plants. Among the factors mentioned are the following:

1. Destruction of weeds, thereby conserving moisture and nutrients, and eliminating competition for light and air.
2. Conserving moisture by the formation and maintenance of a soil mulch.
3. Increasing aeration and thereby favoring nitrification and aiding other chemical changes in the soil.
4. Increasing nitrification through conserving moisture, favoring better aeration, and raising the temperature of the soil.
5. Increasing the absorption and retention of heat.

Effects of Cultivation on Yield.—Cultivation generally increases the yields of crop plants. This is due mainly to weed control, although the formation and maintenance of a soil mulch by cultivation may be an important factor under some conditions. The results of a large number of experiments in cultivating corn carried on in many states show conclusively that weed control is of prime importance.

Data reported by Thompson (1927), and by Thompson, Wessels, and Mills (1931) from experiments carried on in New York as well as results of experiments by Merkle and Irvin (1931) in Pennsylvania show clearly that weed control is of major importance in the cultivation of vegetable crops. The data showing the effects of cultivation as compared with scraping the surface of the soil to control weeds on the yield of six crops grown at Ithaca, N. Y., are shown in Table XI. These experiments were carried on for six years on a sandy-gravelly-loam soil. The treatments were in triplicate. One set of plots was cultivated once a week with a hand cultivator and another set was scraped with a sharp hoe to keep the weeds under control. Weeds were eliminated as a factor in both sets of plots, therefore, the comparison of the yields show the benefits derived from the soil mulch.

The data show little or no benefit from the maintenance of a soil mulch except in the case of the celery crop, the yield of which was increased 24 per cent with highly significant odds. Results of cultivation experiments conducted on a sassafras silt-loam soil on Long Island are similar to those obtained at Ithaca. In the Long Island experiments two cultivation treatments were employed in addition to the scraping to control weeds. One of the cultivation treatments was discontinued when the crops were about half grown, since it was thought that late cultivation might do more harm than good. A comparison of this treatment with the regular cultivation, which continued throughout the period of growth of the crops, gives some idea of the value of late cultivation under the conditions that prevail on Long Island. All treatments were in triplicate. A summary of the data from these experiments, as reported by Thompson, Wessels, and Mills (1931), is given in Table XII.

TABLE XI.—EFFECTS OF MAINTAINING A SOIL MULCH BY CULTIVATION ON THE YIELD OF SIX VEGETABLE CROPS
(Thompson)

Crop	Average yield in pounds per plot of marketable portion of crop			Odds of significance
	Cultivated	Scraped	Percentage increase from cultivation	
Beets	60.57	58.10	4.25	45:1
Carrots	86.68	84.42	2.68	7:1
Onions	77.55	72.01	7.69	49:1
Cabbage	119.03	119.40	None	None
Celery	144.49	116.44	24.00	9,999:1
Tomatoes, untrained	187.96	185.92	1.10	None
Tomatoes, trained	158.61	156.04	1.65	2:1

TABLE XII.—YIELDS OF CROPS IN CULTIVATION EXPERIMENT ON LONG ISLAND

Crop	Number of years	Average yields, pounds per plot			
		Cultivated	Cultivated half season	Scraped	Weeds allowed to grow
Beets	7	240.31	239.72	233.21	45.56
Carrots	5	505.30	506.41	519.50	29.72
Onions	4	67.70	69.60	64.30	3.60
Cabbage	4	233.57	234.56	207.46	129.08
Tomatoes	7	164.03	166.57	166.82	23.28
Potatoes	4	148.35	150.42	158.82	52.67

Examination of the data in Table XII shows no large difference in yield between the plots cultivated throughout the growing season and those cultivated until the crop was about half grown, nor between the cultivated and scraped plots. The only crop in which the difference in yield between the regularly cultivated plots and the scraped plots is statistically significant is the potato and in this case the scraped plots produced the highest yield. Where the weeds were allowed to grow the yields of all crops were markedly reduced. While late cultivation did not increase the average yield it does not follow that late cultivation may not be of value under some conditions. When weed growth is heavy late in the season, late cultivation might be expected to increase the yield. On the other hand when weed growth is light, cultivation after the crop is more than half grown may do more harm than good because of injury to the above grown portion of the plants and to the destruction of the roots to the depth cultivated.

Experiments conducted by Merkle and Irvin on a Hagerstown silt-loam soil in Pennsylvania with potatoes, field beans, cabbage, and mangels gave results similar to those carried on in New York. Mangels was the only crop that gave significantly higher yields from frequent (seven to eight times) cultivation than from scraping the soil. Cultivating three times did not result in higher yields of mangels than did scraping the soil to control weeds. With field beans, cultivating three times, six to eight times, and scraping all gave essentially the same average yields over a period of four years. The results with potatoes over a period of four years show no significant difference in yields between cultivating three times, cultivating six to eight times, and scraping. Cabbage was in the experiment only one year, and, while the scraped plots produced the largest yield, the difference may not be significant.

TABLE XIII.—RELATIVE YIELDS OF SCRAPED AND CULTIVATED PLOTS—YIELDS OF CULTIVATED PLOTS TAKEN AS 1.00

Crop and varieties	Number of years	Unirrigated	Irrigated
Tomatoes, Earliana	3	1.14	0.95
Tomatoes, Marglobe	2	0.95	1.03
Eggplant	3	1.73	1.18
Sweet potatoes	4	1.19	1.15
Potatoes	4	1.11	0.94
Beans, Lima	3	2.13	1.15
Beans, wax	4	1.03	0.98
Cabbage, early	4	1.18	0.97
Average of all crops	..	1.31	1.04

Werner (1933) conducted cultivation experiments on a dark, heavy silt-loam soil in Nebraska with a number of vegetables for a period of four years. Cultivation was done with a hand cultivator with teeth or shovel attachments and scraping was done with a sharp hoe to keep the weeds down and to fill the cracks with loose soil. Both irrigated and unirrigated areas were used for the cultivation experiments and the results are shown in Table XIII.

Results of all cultivation experiments indicate that the main function of cultivation is to control weeds. Maintaining a mulch may be desirable to close cracks in the soil, to reduce surface "run off," and, under some conditions, to conserve moisture by slowing up the movement of moisture to the surface and to increase aeration.

Effects of a Soil Mulch on Moisture Conservation.—One of the benefits claimed for cultivation is the conservation of moisture due to the formation and maintenance of a soil mulch. The usual explanation is that the mulch decreases or stops the capillary flow, and this slows up the movement to the surface, since the moisture would then move by diffusion. Much recent experimental data seem to show that in semiarid regions drying of the surface soils, after a rain or after irrigating, is so rapid that forming a mulch by cultivating is of little or no value. In humid regions it may be an advantage to cultivate after a heavy rain in order to hasten the drying of the surface soil before there is much water lost from lower depths. Data obtained in humid regions indicate that a mulch conserves moisture in a majority of cases, but by no means in all. Results of moisture determinations made on a Dunkirk sandy-gravelly loam soil at Ithaca, N. Y., during the growing seasons 1921 to 1925 are taken to illustrate this point. Soil samples were taken to a depth of 30 inches during four seasons and to the depth of 18 inches the fifth season,

TABLE XIV.—EFFECTS OF A SOIL MULCH ON MOISTURE CONTENT* OF THE SOIL UNDER DIFFERENT CROPS AND IN A FALLOW SOIL
(Thompson)

Crop grown	Average per cent of soil moisture for the growing season, calculated on dry-weight basis									
	1921		1922		1923		1924		1925	
	C	*S*	*C*	*S*	*C*	*S*	*C*	*S*	*C*	*S*
Beets	9.0	8.3	9.8	11.1	8.2	8.0	12.0	11.2	12.1	10.5
Carrots	8.7	8.2	11.1	11.5	9.0	8.0	13.1	12.3	12.7	11.7
Onions	8.7	8.2	11.2	11.2	9.5	9.4	12.0	11.2	11.9	11.4
Cabbage	10.0	9.6	15.2	14.6	10.5	10.6	11.1	10.3	11.4	10.5
Celery	10.1	8.8	13.5	11.7	10.8	8.6	10.8	8.6	10.4	10.0
Tomatoes	7.9	7.4	14.0	12.9	8.7	9.8	11.7	11.6	15.1	12.9
Fallow (No crop)	.....	.....	15.3	14.9	10.3	10.4	11.6	13.2	13.8	12.2
Averages	9.1	8.4	12.9	12.6	9.6	9.3	11.8	11.2	12.5	11.3

* *C*, cultivated once each week during growing season.
S, scraped with hoe when weeds appeared.

from plots producing various crops and from one set of uncropped plots. Table XIV shows the average moisture content of the soil for the season under the different treatments.

A consideration of the data in Table XIV shows that cultivation, as compared to scraping, resulted in the conservation of moisture in 30 out of 39 comparisons, and in loss in seven comparisons, while in the others the two treatments were equal. It is interesting to note that the scraped plots reached a lower moisture content in 24 comparisons and the cultivated plots in 13, while in the other two comparisons both reached the same minimum. In the five years 280 moisture determinations were made on comparable cultivated and scraped plots. In 188 of these the soil from the cultivated plots contained the higher percentage of moisture. In 79 the soil from the scraped plots was ahead, while in the other 13 the moisture was the same under the two treatments.

While the weed plots did not always have the lowest average moisture content for the season, they did reach a lower minimum every year. This suggests that the marked effect of a small growth of weeds may be due to competition with crop plants at a time when moisture is the limiting factor.

There was no definite relation between the average moisture content of the soil for the season and the yield of crop except in the case of celery, where the cultivated soil had the highest moisture and produced the largest yield. With the other crops it did not always follow that the yield was increased by cultivation, even though the soil mulch conserved moisture. In some instances cultivation resulted in loss of moisture at critical periods and in others it conserved moisture when a lower water content was an advantage. When the soil was cultivated soon after a light rain, moisture was lost due to hastening of evaporation by exposing more surface to the drying action of the air. In many instances practically all of the moisture from a light rain was lost by cultivating before the water had penetrated below the depth cultivated. Knowledge of these facts enable one to time his cultivating more intelligently and to reduce or to eliminate the detrimental effects.

Whether or not cultivation will conserve moisture depends on the nature of the crop as to the top growth, the extent and distribution of the roots, the humidity of the air, the velocity of the wind, and the quantity of water in the soil. It has been shown by Viehmeyer (1927) and other workers that a compact dry layer of soil is practically as effective in checking water loss at the surface as is a loose dry layer. Since forming a mulch by cultivation is effective in conserving moisture only when it hastens the drying of the surface, it follows that under conditions of rapid drying cultivating the soil would be of little or no value so far as moisture conservation is concerned. This has been shown to be the case in many experiments in semiarid regions, and was apparently true under some conditions in the experiments at Ithaca, N. Y.

Cultivation may conserve moisture by preventing surface runoff as was shown by Call and Sewell. It seems probable that, in many cases, this is much more important than any conservation due to checking evaporation by the soil mulch. On the other hand, cultivation may have an injurious effect due to the loose soil being washed away during heavy rains, thus leaving the surface uneven with the plants on a ridge. This happened several times in the cultivated plots at Ithaca when the adjoining scraped plots were not injured at all.

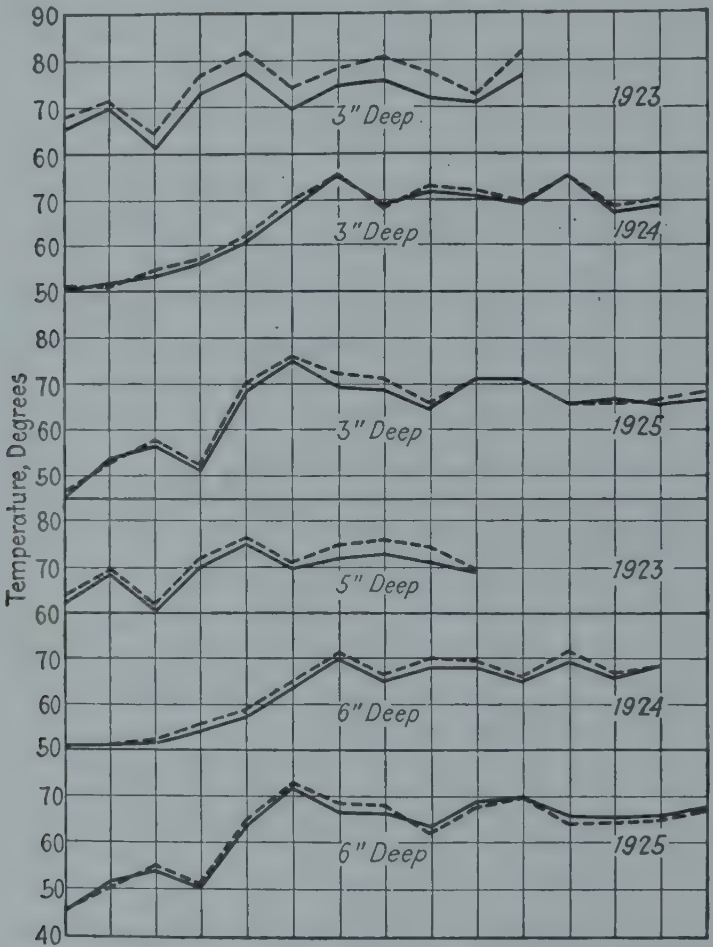

Fig. 9.—Soil temperature (in degrees Fahrenheit) in cultivated and scraped plots of beets. The solid line represents the temperature of the cultivated soil and the broken line the temperature of the scraped soil. (*Cornell Univ. Agr. Exp. Sta.*)

Effect of Cultivation on Soil Temperature.—It is often stated that cultivation of the soil increases the absorption and retention of heat. This may be true for the subsoil, but probably is not true for the surface soil. Bouyoucos (1913 and 1916) working with a sandy-loam soil in Michigan found that uncultivated (scraped) soil at depths of 3, 6, 7, and

20 inches averaged higher in temperature than cultivated soil throughout the growing season. Mosier and Gustafson (1915) found that at depths of 2 and 4 inches uncultivated silt-loam soil averaged higher than cultivated soil during the summer. These studies were carried on for a period of 5 years. The writer (Thompson, 1927) reported results covering studies carried on for 3 years at Ithaca, N. Y., on a sandy loam. The temperature of the soil at depths of 3 and 5 or 6 inches was higher on the scraped plots than in comparable cultivated plots through the growing season every year, regardless of the moisture content of the two. The average weekly temperature is shown graphically in Figs. 9 and 10.

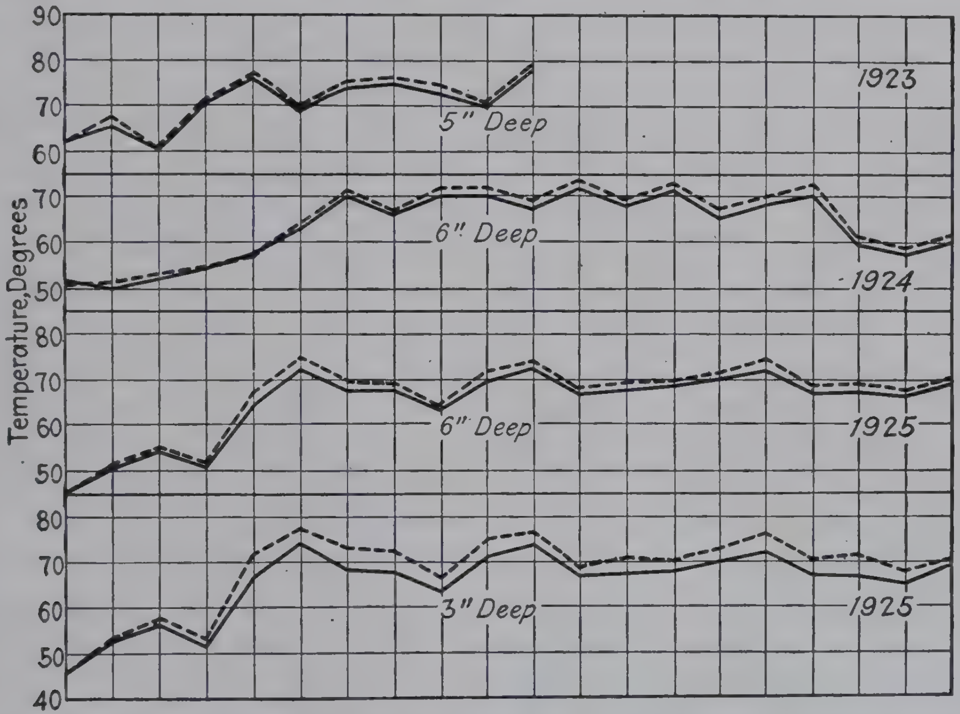

Fig. 10.—Soil temperature (in degrees Fahrenheit) in cultivated and scraped uncropped plots. The solid lines represent the temperature of the cultivated soil and the broken line the temperature of the scraped soil. (*Cornell Univ. Agr. Exp. Sta.*)

The belief that stirring the soil results in raising the temperature is based on the fact that evaporation of water consumes heat. If this were the only factor involved, stirring the soil would raise the temperature whenever it resulted in conserving moisture and lower the temperature when cultivation increased the loss of moisture. In the experiments at Ithaca the scraped soil had the higher temperature when it contained less moisture and when it contained more moisture than the cultivated soil. The compactness of the uncultivated soil probably accounts for the higher temperature. Bouyoucos suggests that the dry layer of loose soil forms poor and imperfect connections with the subsoil and that the heat energy which it receives from the sun is not all conducted downward, but that a large amount accumulates in the surface of the mulch and then some of it is radiated back to the atmosphere. Because of the compactness of the surface of uncultivated soil and consequently better heat conducting power, a greater quantity of heat is carried to lower depths than is the case in cultivated soil. By suspending thermometers 1 inch above the surface of the soil, Bouyoucos found that on some days the temperature was 7° to 10°F. higher over the cultivated than over the uncultivated soil.

The higher temperature in the uncultivated soil would be an advantage under some conditions and a disadvantage under others. However, it is doubtful if cultivation would be justified on the basis of affecting the temperature of the soil.

Effects of Cultivation on Nitrification.—The results of many studies of the effects of the soil mulch on nitrification are somewhat conflicting Any increase in nitrates due to stirring the soil would be the result of improving the conditions for nitrification, as by increasing aeration, providing better moisture or better temperature conditions for the growth of nitrifying bacteria. Since the soil mulch does not always have the same effect on moisture conservation, one might expect that it would affect nitrification differently under different conditions. When moisture is limited, any treatment that conserves it would favor nitrification. It is doubtful if cultivation is of much importance from the standpoint of aeration except on heavy soils.

Nitrate nitrogen determinations made at Ithaca, N. Y., every 2 weeks during the growing season of 1925, show no consistent advantage for the soil mulch on a sandy-loam soil. In two comparisons out of eight there was a significant difference in favor of the soil mulch. Figures 11 and 12 show graphically the quantity of nitrates under the various crops and treatments.

The marked effect of weeds on nitrates is shown in the loss between June 7 and June 22. After June 22 the quantity of nitrates was practically the same under the three treatments and was very low. The growth of crops had a marked effect on the quantity of nitrates. The difference in yield between the cultivated and scraped plots was not sufficient to account for any appreciable difference in nitrates under the two treatments with the exception of celery.

Some investigators have found a positive correlation between soil moisture and nitrates. In the studies reported by the writer there was a positive relation in 12 out of 17 cases, a definite negative relation in two, and no relation or a slightly negative one in the other three. It should be borne in mind, however, that other factors than moisture affect nitrification and nitrate accumulation and might mask the changes produced by increase or decrease in the water content. Temperature has a marked effect on nitrification, and the growth of the crop on nitrate accumulation.

While cultivation does not always increase nitrification, it does often have this effect on heavy soils, where stirring the surface may increase aeration and, under some conditions, conserve moisture. On light soils forming a mulch has relatively little effect on either aeration or moisture conservation.

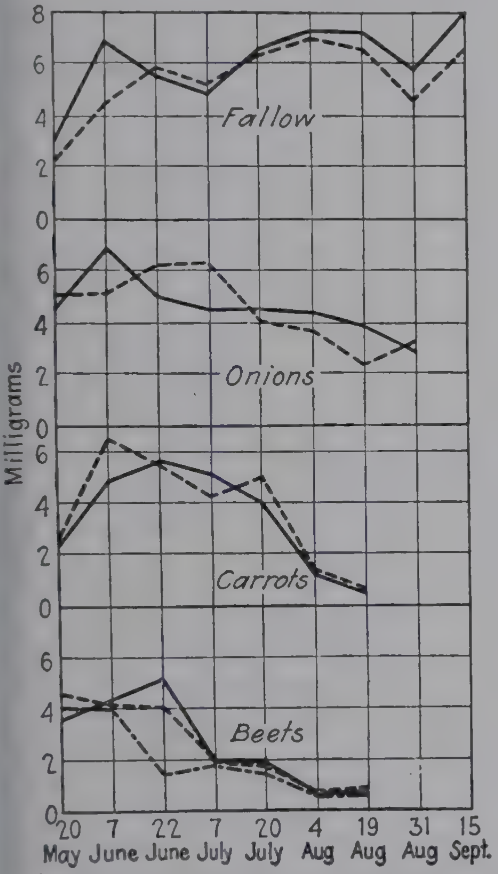

FIG. 11.—Nitrates in cultivated and scraped soil (in milligrams per 100-gram sample of oven-dried soil). The solid line represents the cultivated soil, the broken line the scraped soil and the line of dots and dashes (in beets) the soil on which weeds were allowed to grow. (*Cornell Univ. Agr. Exp. Sta.*)

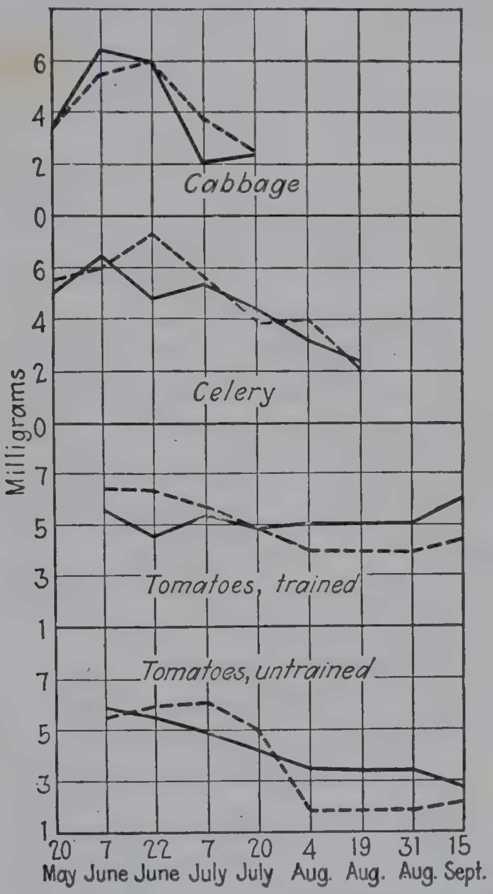

FIG. 12.—Nitrates in cultivated and scraped soil (in milligrams per 100-gram sample of oven-dried soil). The solid line represents the cultivated soil and the broken line the scraped soil. (*Cornell Univ. Agr. Exp. Sta.*)

Cultivating Implements.—Vegetables are cultivated by hand cultivators of the wheel-hoe type, by horse-drawn cultivators, and by tractor cultivators. Hand cultivators are used in commercial gardening mainly for cultivating small-growing crops produced on an intensive scale, and in small home gardens for cultivating all kinds of crops. Horsedrawn cultivators range from the one-horse implement to the two- or three-horse cultivators that cultivate two rows at a time. The large cultivator is not used much in intensive gardening, but is employed in growing such crops as potatoes, cabbage, tomatoes, sweet corn, beans, and others, when grown on a large scale. Tractor cultivators range in size from the small garden tractor to the large-sized farm tractor. However, the heaviest tractors are not well suited to cultivation. There are medium-sized tractors on the market that do satisfactory work in cultivating all crops which are grown far enough apart to give ample space for the wheels. These tractors can be used for cultivating, but they are not practicable for cultivating vegetables grown on an intensive scale.

Garden tractors are being used more and more in intensive gardening. They take the place of hand cultivators and the lighter horse-drawn implements. A careful operator can do practically as good work with a small tractor as with hand implements and better than with a horse-drawn cultivator. Large tractors are not used to any great extent for pulling cultivators, but the so-called garden tractors have become popular during the past few years. They are used mainly for cultivation, but where small-growing crops, such as onions, are grown on a large scale, they are used to some extent for pulling gang seeders. Two or more seeders are fastened in a frame the desired distance apart and the frame is attached to the tractor.

The most successful garden tractors are the relatively small ones used only for cultivation and similar work. A tractor large enough to do satisfactory plowing is too large for the best cultivation, especially for the small crops planted in rows 15 to 24 inches apart. A tractor for cultivating small crops on loose friable soil need not have so much power as one used on heavy soil. Most of the garden tractors are equipped with various attachments for almost any kind of cultivating.

Garden tractors and hand cultivators are used very largely for cultivating small-growing crops produced on an intensive scale. Most of the onions, lettuce, and carrots produced on muck soils in the East are cultivated by these implements. These cultivators save much hand hoeing and hand weeding as they can be run close to the row. They can be used when the plants are very small, or even before they come up, and this enables the grower to keep ahead of the weeds.

Various types of attachments can be used on all of the kinds of cultivators mentioned. The common attachments are the shovels, such as are used on the three- and five-shovel horse-drawn cultivators; teeth, such as are found on the 13- and 15-tooth cultivators; blades that run just beneath the surface soil, cutting off the weeds and leaving a thin mulch; disks and rake-like attachments used to some extent on hand and small-tractor cultivators. The "sweep," commonly used in the South, and the blade attachments such as are employed on hand cultivators are very efficient in controlling weeds and they are less destructive of the roots of crop plants than are the shovel and teeth attachments. In cultivating most vegetable crops there is little need for the shovel-type of cultivators. They leave the soil surface uneven and destroy many roots. More use should be made of the blade attachments.

Hoeing and Weeding.—Intensive gardening requires considerable hand hoeing and weeding, and even in less intensive types of vegetable growing some hand work is required. Hoeing, or weeding, is essential for keeping down weeds between the plants in the row. No matter how well the cultivating is done some hand work is desirable if not absolutely essential. With good cultivation and hoeing very little weeding needs to be done by hand on most crops, but with celery, lettuce, onions, and the root crops, especially on muck, hand weeding is one of the most expensive and most laborious operations. The aim should be to reduce hand weeding to the minimum.

When and How to Cultivate.—Since weed control is the most important function of cultivation, it follows that the work should be done at the time most favorable for killing the weeds. This is accomplished most easily before the weeds have become established and it is important to kill them before they have competed seriously with crop plants for moisture and nutrients. The best time to cultivate is just as the weeds are breaking through the surface because at this time the roots are small and do not have much of a hold on the soil. At this stage shallow cultivation is all that is necessary, whereas, if the weeds are allowed to get large, deeper cultivation is necessary unless a blade type of cultivator or the "sweep" is used. Deep cultivation destroys many roots and prevents the plants from getting the full benefits of the surface soil.

When feasible, cultivation should be given as often as necessary to prevent weeds from injurying crop plants. This means frequent cultivation when conditions are very favorable for the growth of weeds, as after a rain or an application of irrigation water followed by good weather for growth. There is no justification for the practice of cultivating once a week or once in 2 weeks regardless of the conditions. Under some conditions it is desirable to cultivate more often than once a week and under others a month might elapse between cultivations without harm. When there is no weed growth and a soil mulch is already formed, not only is further cultivation an unnecessary expense, but it is usually injurious due to the destruction of roots and to bringing moist soil to the surface to dry out. If 3 or 4 inches of surface soil is kept stirred, most of the roots are destroyed so that it is impossible for the plants to utilize the nutrients in the richest soil.

Generally, if sufficient cultivation is given to keep weeds under control, it will be enough to accomplish all other purposes. Under some conditions, especially on heavy soils in humid regions, cultivation is probably desirable from the standpoint of forming a soil mulch even if there are no weeds. This depends, however, to some extent on the crop grown and on the stage of growth. Crop plants that have a large and well-distributed root system are less benefited by a soil mulch than those that have a small, poorly distributed system. When plants are small they are more likely to be benefited by the mulch than when they are large. This is explained by the fact that the large root system intercepts more moisture as it moves upward, therefore, less reaches the surface where evaporation takes place, than would be the case with a smaller root system.

Cultivation immediately after a rain of ½ inch or less is likely to do more harm than good, due to hastening the drying of the surface soil, which contains most of the water from such a rain. The destruction of the roots in the wetted surface would also prevent the plants from getting benefits from the rain.

Shallow cultivation is preferable to deep cultivation for all vegetable crops under most conditions, especially after the roots have grown to any considerable extent. In the spring, when it is desired to have the surface soil dry out, deep cultivation may be justified provided the roots are not destroyed. Practically all of the benefits derived from cultivation are secured through shallow tillage. When deep cultivation is practiced during the early stages of growth, the depth should be lessened as the plants grow large and the roots increase in length.

PAPER MULCH

The use of paper mulch in vegetable growing was much discussed some years ago following its successful use in connection with the growing of sugar cane and pineapples in Hawaii. Interest in mulch paper was stimulated by the publication of results obtained by Flint (1928) in experiments carried on at the Arlington Experimental Farm and at Aurora Hills, Va. He worked with 24 different kinds of vegetable crops, 12 of which were in the tests more than a year. In all, Flint had 31 trials with vegetable crops and the paper mulch increased the yields over those obtained by clean cultivation. Most of the increases were large—much larger, in fact, than were obtained by other experimenters. It should be noted, however, that where Flint obtained very large increases from the paper mulch the yields of the cultivated plots were very low, which indicated that the soil was unsuited to the crops being grown.

Results of experiments by Flint, by Magruder (1930), by Thompson and Platenius (1931), and by Hutchins (1933) show that the paper mulch increased the yields of many vegetable crops and also hastened maturity of most of them. The paper also keeps the product off the ground and this is of considerable importance with some crops, such as tomatoes and melons, under certain conditions. In spite of these advantages, paper mulch has not come into commercial use to any great extent in the United States largely because of the cost of the paper. It has been, and is still used on a small scale by melon growers in some areas. Hutchins points out that mulch paper appears to be most beneficial under conditions that are unfavorable to the optimum development of the crop such as poor soil, deficient moisture, and low temperature. Warm-season crops of high yields and high value per acre are most likely to give the best results.

While the paper eliminates weeds in the covered area and cuts down the cost of cultivation this is offset to a large extent by the cost of laying the paper and by the additional cost involved in planting when paper is used.

Results of studies on soil moisture by the investigators mentioned and by Stewart, Thomas, and Horner (1926) show that, in most cases, the mulch paper conserved moisture in the surface soil. This conservation is an advantage when the moisture is below optimum and a disadvantage when it is above optimum for any given crop.

Results of most studies indicate that it increased the temperature of the soil, but Stewart, Thomas, and Horner point out that the temperature effect of the paper varied with the weather and the season of the year. The greatest difference in temperature between mulched and bare soil was shown in the warmest weather, while rainy and cloudy weather decreased the temperature difference.

Mulch paper increased nitrification in the experiments of Stewart, Thomas, and Horner and of those reported by Thompson and Platenius. This increase in nitrification probably is related to soil moisture and soil temperature, both of which were higher in the mulched soil.

CHAPTER XI

IRRIGATION

Irrigation is essential to successful growing of vegetables in arid and semiarid regions; in humid regions it is an insurance against drought. It is only within relatively recent years that the desirability of supplementing the rainfall in humid regions has been recognized. Irrigation is used to a considerable extent in vegetable growing on high-priced land and its use is increasing each year. There is seldom a growing season in humid regions in which there are not periods when water is a limiting factor in crop growth, and it is during such periods that irrigation is of greatest value. A short period of dry weather often reduces the yield and lowers the quality of the product materially, and a prolonged drought may result in a total loss.

Under most conditions, even in humid regions, larger crops of better quality can be produced with irrigation than without it. The individual grower must determine for himself whether or not the increase in yield and quality he is likely to get over a period of years will pay for the cost of the irrigation system and its operation. Irrigation often is of special value just after seeds are planted, especially if the soil is dry at the time. It is also of particular value when plants are set out during dry weather. It should be borne in mind, however, that whenever there is a deficiency of soil moisture during the growing period for any crop, irrigation would have a marked effect on growth.

As an illustration of the value of irrigation in humid regions an experiment carried on in Michigan in 1920 may be cited. Loree (1921) reported results of this experiment in which the yield of crops grown under irrigation was compared to the yield of the same crops grown without irrigation in adjacent plots. The increase in yield under irrigation was as follows: cabbage, 81 per cent; onions, 233 per cent; beets, 86 per cent; carrots, 66 per cent; and lettuce, 60 per cent. In addition to the increased yield due to irrigation the quality of many crops is greatly improved due to continuous growth. Irrigation makes possible more intensive cropping and often hastens maturity.

There are three general methods of irrigating land: surface, subirrigation, and spray or sprinkling. Sprinkling or spray irrigation is, in reality surface irrigation, but in common usage the term surface irrigation means applying water by flooding, or by means of a trench or furrow.

Surface Irrigation.—Surface irrigation is extensively employed in the arid and semiarid sections of the United States, but has not become popular in the eastern part of the United States. This method of irrigating requires level or nearly level land and for this reason it has not been used to any great extent in the East where the surface soil is shallow and will not permit of much grading.

The furrow method of surface irrigation consists of running the water through furrows between the rows of plants in such a way that it will moisten the soil between the furrows. When plants are to be set out, the furrow often is made in advance of planting. In this case the plants are set on the side of the furrow or in the bottom of it, the former method being used on heavy soil and the latter on light or medium soils. After the growth is well started, the furrow is shifted to the center between the rows. When the soil is very dry and porous, a preliminary irrigation may be given before planting. If the plants are set in dry soil, it is desirable to have water applied soon after setting to prevent serious wilting.

The main advantage of surface irrigation over the other kinds is the low cost of equipment. With nearly level land little expense is involved in making the furrows and the outlay for equipment is small as compared to the spray method of irrigating. On the other hand, any method of surface irrigation requires considerable labor to distribute the water properly. Other disadvantages of surface irrigation are: (1) uneven distribution of the water, (2) loss of water in open porous soils, and (3) puddling and baking of the soil in the furrows following the application of water. However, where the land is nearly level and a cheap supply of water is available, this method is satisfactory. Where a stream can be diverted and water run to the fields by gravity, or where flowing wells are available, surface irrigation is a cheap method.

Irrigation by flooding is used in growing Bermuda onions in Texas and other varieties of onions, as well as some other crops, in other sections of the Southwest and West. This method is not satisfactory for all crops and is usable only on land that is level, or nearly level. Any given bed irrigated by this method must be practically level; hence where the land is uneven it requires grading. The area to be irrigated by the flooding method is diked with soil and the bed is flooded with water. The land is prepared for irrigating by throwing up narrow ridges across the area to be planted. The width between these ridges in the Bermuda onion fields of the Laredo, Tex., district is 15 to 16 feet. If the surface has much slope the ridges should be made across the slope about 12 feet apart. The length of the borders between the laterals is governed by the slope of the surface. Where the slope is slight the length should be not over 60 to 75 feet between laterals, but where the slope is considerable the borders may be 100 feet or more long.

The main laterals, used in the flooding method, should be constructed so as to be slightly above the level of the surface in order to give a good head to the water to the smaller lateral ditches. The bottom of minor laterals should be kept level with the surface of the field so that they may be drained after the field has been irrigated. The size of the minor laterals and main ditches is determined by the quantity of water they are to carry.

Subirrigation.—This method consists in delivering the water to the plants from below. The advantages claimed for subirrigation are as follows: (1) the water supply is constant; (2) the surface soil is kept dry which prevents rapid evaporation; (3) the soil is not puddled, therefore, the surface does not bake. The main disadvantage is the large quantity of water required. Subirrigation is not satisfactory where the subsoil is porous, or where there is a hardpan or impervious subsoil near the surface. For successful subirrigation the land must be level, or have a slight and uniform slope.

Spencer and Berry (1916) give the following as essentials for the successful operation of subirrigation systems: (1) an abundant and cheap water supply; (2) a subsoil floor of clay, marl, or hardpan located at a depth of 3 to 5 feet below the surface; (3) a foot or more of coarse sand on top of the subsoil; (4) a top soil of sandy loam that is neither too porous nor too compact, and which will convey water freely; (5) land that admits perfect drainage; and (6) land that is level without depressions or raised places.

In the vicinity of Sanford, Fla., where subirrigation is used extensively, the water is supplied by artesian wells, obtained by driving pipes down into the artesian stratum and allowing the water to rise to a height above the surface of the ground. In some instances force pumps are used where the water rises to within easy reach from the surface. The water is conducted through laterals made of 3-inch drain tile with the lines 24 feet apart. These tiles are placed at least 18 inches deep and have a fall of 1 inch or more to every 100 feet.

Spray Irrigation.—Overhead spray irrigation is the method most commonly used in the eastern part of the United States. By this method water is applied to the surface soil in the form of a spray or mist similar to a gentle rain. It is an outgrowth of city lawn sprinkling. Some of the advantages are: (1) it can be used on land so uneven that it would be impracticable to use other types; (2) it can be used on soil that is too porous for either furrow, or subirrigation; (3) it requires less labor to operate than does surface irrigation; (4) the water is distributed more uniformly by this method than by any other; (5) it causes less washing and less puddling of the soil than does surface irrigation. Spray irrigation systems are sometimes used to prevent the blowing of light, dry soil and to prevent frost injury under some conditions. The main disadvantage of this method of irrigation is the cost of materials, equipment, and installation. The cost is so high that it is justified in humid regions only in connection with the growth of crops that bring high returns per acre.

Types of Spray Irrigation Systems.—The system most commonly used in the eastern part of the United States consists of parallel lines of pipe placed about 50 feet apart and supported on posts extending about 6½ feet above the surface of the soil. Each line of pipe is equipped with small nozzles spaced 3 to 4 feet apart. These nozzles are screwed into holes bored in the pipes with a drill. Each nozzle discharges a small stream of water at right angles to the pipe line. The entire width of about 50 feet can be irrigated from one line of pipe by turning the pipe lines. The water is pumped through underground pipes to which the end of each line is connected by an upright feed pipe. Each nozzle line has a valve at the intake end, an automatic turning device or a turning union with a handle to turn the pipe, and a screen to catch any sediment in the water.

The kind of system described above is known as a "high-post installation." Posts 1½ to 4 feet high are less frequently used and the system is called "low-post installation." A third type of installation has the nozzle lines suspended by short wires from a cable supported by posts 12 to 20 feet high and 50 to 125 feet apart. The so-called high-post installation is the most popular as the lines of pipe are placed high enough above the ground to allow a team or tractor to pass under them but are not so high as to be hard to reach to clean the nozzles and to make repairs. The low-post system gives a slight saving in cost of posts, but interferes more with farming operations than the high-post installation. The high-post installation is more effective in spreading water over the field, especially when there is only a light breeze stirring. The cable-suspension installation interferes less with farming operations than any other, but, when the nozzle lines are more than 6½ feet from the ground, the nozzles are less easily cleaned and repairing is made more difficult than with the other two types of installation.

A portable spray system is coming into use in many localities. It consists of one or more nozzle lines that are carried from one part of the field to another as needed. The lines are laid on the ground, or supported on boxes or special supports. The main pipes to supply the nozzle lines sometimes are laid on top of the ground and moved from place to place. The main advantage of the portable system is the lower cost of installation. The cost of operation is greater owing to the additional moving of the pipes and making the connections and disconnections. When portable lines are used the system is out of the way during plowing, cultivating, spraying, and harvesting, and there is no waste of land.

Another type that has been developed in California in recent years and is coming into use in other parts of the United States is the portable rotary sprinkler system. This consists of a light-weight, portable pipe line with rotary sprinklers mounted on it at varying intervals, depending on the kind of sprinklers used, but usually about 40 feet apart. Some of the sprinklers in most common use cover a circle about 90 feet in diameter so that by spacing them 40 feet apart they lap each other a little over half. Ten nozzles in one line would water a strip 90 feet wide and 400 feet long. The edges of the strip are not fully watered, but by spacing the sprinkler lines at 80-foot intervals, thereby lapping the edges 10 feet, a fairly uniform application is obtained. When one strip is irrigated the entire sprinkler line is moved 80 feet and another strip is watered. According to Durfee, Bruhn, and Witzel (1936) with an installation of the type described and with each sprinkler head discharging 16.67 gallons per minute, the line will apply one-half inch of water an hour to the main part of the strip. One line 400 feet long with 10 sprinklers operated as mentioned would apply about one inch of water to about three acres in 10 hours. Operating 10 hours a day for 6 days a week, this one line would supply one inch a week to 18 acres. One of the principal reasons for the success of this system is the use of thin-walled, light-weight pipe that is put together quickly without the use of any tools. One advantage of this over the small nozzle system just described is that less time is required to apply a given quantity of water. Another advantage is that no supports are necessary as the pipe rests on the soil and the risers are screwed into the pipes.

The most popular type of rotary sprinkler has two nozzles, one that waters the area immediately around the risers, and the other covering the remaining area. These sprinklers are operated by the water pressure and revolve very slowly.

Staebner (1931) reported tests of various types of sprinklers and found that more uniform distribution over a large area can be obtained with the overhead-pipe system than with any other type of spray irrigation available. "This is because each unit wets approximately rectangular areas and when properly handled will wet quite uniformly. Furthermore, the areas irrigated by adjacent units join without serious overlaps and without serious gaps." During the past few years there has been considerable improvement in rotary nozzles so that more even distribution of water is possible than was possible with the older types.

Still another type of irrigation is the distribution of water through a porous hose, in which the water oozes through the walls of canvas hose. This system is lower in first cost, requires more labor for operation, and is less durable than the spray systems described. The porous hose type of distribution is not satisfactory where the land is uneven, more water being discharged in the low places than elsewhere, resulting in uneven distribution. This method of irrigation has not become very widespread.

Cost of Spray Irrigation.—The cost of spray irrigation varies widely, depending on the type of installation and other factors. In a survey made in New Jersey by Huber, Gross, and Lucas (1927), it was found that the average cost of installing permanent systems was $415.30 and for movable systems it was $124.41. The permanent lines require less labor for operating and last longer than movable lines. According to the New Jersey survey, the life of permanent lines was estimated at an average of 22.68 years as compared to 18.78 years for movable lines. The estimate for all irrigation lines as given by 164 farmers was 21.05 years.

The cost of installation of both permanent and movable systems varied considerably, depending on the water supply, kind of power used, and method of installation, as is shown in Table XV.

Table XV.—Average Cost of Spray Irrigation per Acre in New Jersey
(Adapted from *N. J. Agr. Exp. Sta. Bull.* 453)

Item	Water supply			Power unit		Installation		Average all irrigation
	Well	Surface water	City water	Motor	Engine	Self	Contract	
Permanent								
Investment	$430.91	$526.42	$270.77	$483.57	$442.65	$391.85	$481.90	$415.30
Operating	18.15	18.57	32.63	24.31	16.47	....	....	23.37
Repair	4.69	2.23	2.49	5.57	4.25	....	....	4.40
Movable								
Investment	$203.03	$500.00	$ 68.70	$350.00	$253.03	$144.85	$ 94.29	$124.41
Operating	10.92	no data	31.95	18.75	7.01	....	....	30.50
Repair	14.97	no data	4.16	10.71	19.23	....	....	5.96

In considering the above estimates on the investment in irrigation systems it should be borne in mind that the costs are for a period from 1909, or earlier, to 1925. Costs in the future may be very different from those of the period mentioned.

Accurate estimate of the cost of any irrigation system can be made only by taking into consideration the location of the farm and the conditions under which the installation is to be made. Prices of materials and labor differ widely in different localities and from time to time. A good estimate of the cost of any installation can be made by preparing a bill of materials and getting quotations from dealers and obtaining local estimates on the cost of the well or other water supply. Manufacturers of spray irrigation equipment often furnish, on request, bills of materials and plans for an irrigation system.

It is probable that the cost of installing a portable rotary sprinkler system is less per acre than that for the oscillating pipe line system, especially where relatively large areas are to be irrigated. With the rotary system described, an inch of water is applied in about two hours while with the other type it takes about 10 hours to apply one inch.

Planning an Irrigation System.—The first step in planning an irrigation system should be to make sure that an adequate supply of water is available during the driest seasons. The next step should be to get all available information in order to determine the kind that would be most feasible under the particular conditions. Irrigation specialists suggest that for the usual kinds of vegetables grown under irrigation in the eastern part of the United States the spray outfit should be able to deliver at least 1 inch of water per week over the area to be irrigated. This quantity is equivalent to 27,152 gallons per week for each acre. The water should be free from materials that would injure plants and free from dirt and sand that would clog the nozzles. If there is a choice of sources of water supply the cost of the original installation and of operation and upkeep for each source and the dependability should be given consideration before making a choice. When there is any question as to the adequacy of the supply it should be tested to determine the quantity of water available. Mitchell and Staebner (1927) suggest the following method:

> The supply obtainable from a well should be tested. This can best be done with a pump and engine running a 10-hour test. A barrel of known capacity can be set under the discharge pipe, and the time required to fill it measured once an hour during the test. The prospective irrigator should then attempt to estimate how much this flow probably will be reduced during the driest season of the year. For watering 2 acres, 15 to 20 gallons per minute through a period of 10 hours should be obtainable at any time. This quantity is generally considered the minimum practicable to use for irrigating anything more than a home garden. For a larger area the supply should not be less than 7½ to 10 gallons per acre per minute. If more than one well is required, each succeeding one may be expected to deliver less water than the last, how much less depending upon the distance between them and the nature of the water-bearing material.
>
> If the source of supply is a lake or stream, general knowledge of the stages of flow usually will indicate whether the supply is sufficient; if it does not, the flow in a stream can be measured by a triangular weir, as described in another publication. The flow of a very small stream, even sufficient to irrigate 4 acres, can be measured with a barrel or a pail. If a small wooden dam will not raise the water high enough to flow into the measuring receptacle, a barrel can be set in

the bed of the stream and a count made of the number of pailfuls taken out per minute in order just to keep the barrel from overflowing.

Since the laying out and installing of an irrigation system require a considerable knowledge of engineering, the reader is referred to special books and bulletins written by irrigation specialists.

Applying Water.—In applying irrigation water it is desirable to moisten the soil thoroughly to the depth of several inches rather than to moisten only 1 or 2 inches of the surface at frequent intervals. The surface should not be kept wet. With the overhead system it is best to apply the water slowly enough not to puddle clay soils; this requires frequent turning of the nozzle lines. An automatic turning device will take care of this. Water should be applied as often and in such quantities as needed to keep the soil in the best condition for the crops grown. The frequency of watering and the quantity of water needed depend on the utilization of water by the crop and the loss by evaporation from the surface. The rate of use depends on the leaf area of the crop and the transpiration rate, while the rate of loss by evaporation is governed by the evaporating power of the air. The latter is determined by atmospheric humidity, temperature, wind velocity, and other factors. Because the use of water by the crop and the loss by evaporation vary widely no rule can be given as to how often water should be applied. The condition of the soil and the appearance of the crop are the best guides.

One should be careful not to apply so much water that the soluble fertilizers would be leached out, as might occur where the surface soil is shallow and the subsoil is gravelly. On the other hand, where the surface soil is deep it would be better to apply enough water to moisten to a considerable depth rather than to keep only the surface 6 or 7 inches moistened. On a hot, dry, windy day more water would be lost by evaporation before it penetrated the soil than would be the case if the water were applied on a cloudy, cool day. There is urgent need for more information on the time and method of applying water and the quantity to be applied under varying conditions of climate and soils and for different crops.

CHAPTER XII

ROTATION, SUCCESSION, AND INTERCROPPING

ROTATION

The term rotation, as applied to crop production, may be defined as a systematic arrangement for the growing of different crops in a more or less regular sequence on the same land. Rotation differs from succession cropping in that the former covers a period of 2, 3, or more years, while the latter refers to the growing of two or more crops on the same land in one year. Systematic crop rotation is not so common in vegetable growing as in general farming. It is, however, important in vegetable growing and should be planned and followed as systematically as feasible.

The benefits derived from crop rotation are due largely to the control of disease and insects, and to the better use of the resources of the soil.

Rotation as a Factor in Disease and Insect Control.—Many serious diseases can be controlled in a practical way by a systematic rotation in which the host plant is grown on the same land not oftener than once in 3 or 4 years. Rotation is effective in disease control mainly with those diseases whose spores or other propagating parts live only 1 year or 2 years. Club root of cabbage and other crucifers can be controlled by keeping the land free of cruciferous crops and weeds for 2 years. Other diseases, such as the potato scab and onion smut, cannot be controlled by ordinary rotation, since the organisms involved live in the soil for several years. In planning a system of rotation from the standpoint of disease control, one needs to know what kinds of crops are affected by a given organism. Some organisms attack only one host plant, others affect only those that are closely related, while still others are not limited even to the same species, genus, or family. The nematode disease is serious on a large number of kinds of crops representing many families.

Rotation is of value in the control of some kinds of insects, especially of species which feed on only one crop and which are unable to move very far. If the host plants are not near at hand when the insects emerge many will perish before reaching them. With most insects a short rotation is as effective as a long one since they die in a short time after emergence if their food plants are absent. In planning a rotation for insect control one should follow a crop which has been infested by one known not to be attacked by the same insect.

Effect of Crop Plants on Those That Follow.—It is a fairly common belief among vegetable growers that certain crops depress the yields of others that follow. It is the belief among muck soil truckers that carrots have a depressing effect on the yield of onions, celery, and lettuce as compared to the effect of these crops on each other. There is considerable evidence to indicate that the previous crop has an important relation to the yield of a crop following. Experimental results published by Hartwell and Damon (1918), Hartwell, Pember, and Merkle (1919) and Hartwell, Smith, and Damon (1927) give the best evidence available on the effects of various crops on those that follow. The plan of this experiment is to grow 16 different crops on as many plots for two seasons prior to growing one of these on the entire area every third year. The plots are all fertilized alike, both for the miscellaneous crops and for the individual crop, the third year. Beginning in 1908, the 16 crops were grown for 2 years and were followed by onions in 1910. Buckwheat was the crop grown on all of the plats in 1913, alsike clover occupied all of the plats in 1916 and 1917, mangels in 1920, and carrots in 1923. The data on the yields of these five crops are given in Table XVI.

TABLE XVI.—EFFECT OF CROP PLANTS ON THE YIELD OF THOSE THAT FOLLOW

Previous crop	Yield of crops per acre, total					
	Onions, bu., 1910	Buckwheat, bu., 1913	Alsike clover, tons		Mangels, tons, 1920	Carrots, bu., 1923
			1916	1917		
Onions	289	20.8	1.80	2.06	41.5	999
Potatoes	110	22.7	1.95	1.58	40.0	877
Beets, mangels	72	20.5	1.78	1.88	25.5	895
Rutabagas	99	33.8	1.74	1.99	39.7	929
Cabbage	88	20.2	1.73	1.95	40.8	802
Buckwheat	112	13.0	1.71	1.80	40.8	843
Corn	286	5.4	1.69	2.14	38.9	894
Millet	319	4.4	1.71	1.61	39.1	897
Oats	346	15.0	1.69	1.99	41.8	709
Rye	187	21.5	1.97	2.28	39.3	823
Timothy and redtop or carrots*	515	7.5	1.52	1.08	40.8	692
Redtop	524	9.6	1.97	2.36	38.6	830
Timothy	362	4.4	1.69	2.12	40.2	866
Squash	362	22.5	1.93	2.23	40.7	889
Clover, alsike	415	7.3	1.29	1.24	40.0	797
Clover, red	249	7.5	1.41	1.28	39.9	845

* Timothy and redtop were grown on this plot in 1908, 1909, 1911, and 1912, and carrots in 1914, 1915, 1918, 1919, 1921, and 1922.

The data in Table XVI show a very marked variation in yield of onions and buckwheat following the different crops and, in general, the crops which had the most depressing effect on the yield of onions had the opposite effect on buckwheat. The yields of alsike clover, mangels, and carrots show much less variation than do the yields of onions and buckwheat. The large variation in yield of onions and of buckwheat following the various crops is due probably to their varying effects on soil acidity and on the quantity of nutrients removed. It was found that the lowest yield of onions followed those crops that removed the largest quantity of the deficient nutrients and the largest yield followed redtop, which removed the smallest quantity of nitrogen and phosphorus. The yield of buckwheat did not follow the same order. It was not universally true, however, that the crops which removed the largest quantities of the deficient nutrients were the ones that had the most depressing effect on the succeeding crop. This was shown by Hartwell, Pember, and Merkle (1919) in results of studies made in glass houses with buckwheat, mangels, rye, onions, and redtop. Plants of these five crops were grown in pots for 2 years and then onions were grown in all of the pots the third year. Fertilizers were added in optimum and superoptimum quantities, and while the yield of onions was less divergent following these five crops than had been the case in the field, there was still considerable difference.

The soil acidity is affected differently by the several crops and this may account for considerable difference in yield of crops which are sensitive to acid-soil conditions when following others that increase acidity. It was found that the yield of onions was highest following those crops giving rise to the least acidity. When the soil acidity was reduced by liming the effects of the various crops was much less divergent. Mangels and buckwheat increase the acidity of the soil while redtop decreases it. The less divergent effects of previous crops on the yields of mangels and carrots, as compared to onions and buckwheat, may be accounted for by the difference in soil treatment. In later years attempts have been made to have the uniform fertilizer supply the average of the optimum requirements of the crops as determined by tests made in drain tiles sunk in the soil contiguous to each plot. This has tended to reduce differences due to difference in nutrients removed by previous crops. The acidity has also been reduced by liming.

Results of later experiments at the Rhode Island Station, reported by Odland, Smith, and Damon (1934), indicate that the divergent effects of crops on succeeding crops cannot be explained entirely on the basis of nutrients removed and on difference in soil reaction. Differences in depth and distribution of roots and in the quantity and quality of organic residues may account for some of them. Crop residues with a high carbon-nitrogen ratio might depress yields of the following crop because of the competition between the microorganisms, causing decomposition, and the crop plants for available nitrogen.

The reduction in yields of crops accompanying high acidity may not be due to acidity in itself, but to toxicity of some compounds that are soluble in acid solutions, but are rendered insoluble by liming.

Order of Crop Rotation.—While it is impracticable to outline a definite rotation to follow under all conditions, there are a few principles that should be observed. To utilize fully the resources of the soil it is well to alternate shallow-rooted and deep-rooted crops and to follow crops that furnish organic matter with those whose culture favor its decomposition. In order to grow as much organic matter as is feasible, and at the same time, not sacrifice money crops, the rotation may be so planned as to give time to grow some soil-improving crop. In the North this can be done by following a crop harvested in late summer or early autumn by an early crop the following spring, and by following a crop which is harvested late in the fall with one which is planted late the following spring. In the first case a green-manure crop planted as soon as the ground is available will make considerable growth before winter and may be turned under early in the spring. In the latter a green-manure crop planted late in the fall will make most of its growth in spring and may be plowed under in time for a crop which is planted the latter part of May or early in June. In sections in the South where the soil-improving crop is grown in summer the same principle holds. Planning the cropping system so as to grow soil-improving crops without giving up a money crop is discussed in Chap. V.

In many sections vegetable crops are grown in rotation with general farm crops. This is especially true in regions producing late potatoes, late cabbage, and in growing canning crops, such as tomatoes, peas, sweet corn, and beans. In such cases a small grain crop may well follow the vegetable crop, and this, in turn, may be followed by a legume hay. The sod land may then be planted to corn and followed by the vegetable crop the next year, or the vegetable crop may follow the hay unless weeds or insect pests are likely to be troublesome. For small-growing vegetables like beets and carrots a clean-culture crop should usually precede.

SUCCESSION CROPPING

Succession cropping is the growing of two or more crops on the same land in one growing season. For success this requires heavy fertilization and good cultural practices. Succession cropping is practiced by all market gardeners and by many truck growers who operate on high-priced land. Under such conditions it is necessary to keep the land occupied with a money crop for a large part of the growing season and by planning the cropping system carefully two, three, or even four crops may be grown in 1 year. The number of crops that can be grown depends largely on the kind of crops and the length of the season. In planning for succession cropping the same principles should be observed as in planning a rotation. Special attention should be given to growing soil-improving crops.

As examples of succession cropping the following might be mentioned: (1) early lettuce or radishes followed by beans, and these by fall turnips or spinach, (2) early cabbage followed by late potatoes, where the growing season is long enough, (3) early potatoes followed by late cabbage, (4) early carrots or beets followed by beans, (5) lettuce followed by late celery, a practice often followed on muck land in New York. All kinds of combinations can be worked out to meet the needs of the individual grower and his market requirement. The plan should be worked out in advance so that the land, labor, and equipment may be utilized to the best advantage. It is not to be expected that any definite plan made in advance would always be carried out as weather, pests, or change in prospective market demand might make a change desirable. Any plan of cropping system should have some flexibility and this ought to be taken into consideration in making it.

INTERCROPPING OR COMPANION CROPPING

When two or more crops are grown together on the same land the system is known as intercropping or companion cropping. This may embrace succession cropping as in the planting of cabbage, lettuce, and radishes at the same time. The radishes mature and are removed first and then the lettuce will follow. Both will be out of the way before the cabbage needs all of the space. Intercropping is practiced mainly by market gardeners on high-priced land and where much of the work is done by hand. Gardeners of foreign extraction are more likely to follow this system than are American gardeners. In the United States intercropping is becoming less and less followed due to the extra labor required.

The main advantages of intercropping are: (1) economy of space, which is important with high-priced land, (2) saving in tillage as the same plowing and fitting of the land serve for two or more crops, (3) more complete utilization of the nutrients, any surplus applied to one crop being available for another, and (4) increased gross returns from the area cultivated. These advantages may be more than offset by the following disadvantages: (1) increase in labor costs due to the necessity for a large amount of hand labor and the impracticability of using large cultivating implements, (2) larger demand for nutrients and moisture, and (3) greater difficulty in controlling insects and diseases. The increased demand for moisture might be serious during dry periods. In disease and insect control one crop might be injured by the material used for controlling the pests on another. There is also the danger of injuring one crop when another is being harvested.

For intercropping of the intensive kind to be successful, an abundant supply of labor must be available. It is not practicable, under most conditions, where land values are low and labor costs high because large implements cannot be employed to advantage under most kinds of intercropping.

In planning intercropping, the grower should consider the time each crop is to be planted, the habit of growth, the space required by each at various stages of growth and the time when each is expected to mature. Care should be exercised to prevent one crop from seriously interferring with another at a critical period of development. Intercropping is more likely to be successful where irrigation is practiced than where dependence is placed on rain alone for the moisture supply.

Various plans of intercropping are used by market gardeners and in nearly all of them small-growing, quick-maturing crops are planted with larger, later-maturing ones. Radish and lettuce are often planted as intercrops with cabbage or other similar crops. Cabbage and tomatoes may be grown together, the cabbage plants being set early in the season and tomatoes set between the rows. Under this system the rows of cabbage plants are farther apart than under the single crop system. The early cabbage will be ready to harvest before the tomato plants need the space. On Long Island some growers who produce early potatoes and late cucumbers leave out every other or every third row of potatoes and plant cucumber seed in this space after the potato crop is nearly grown. The potatoes are harvested before the cucumber plants need additional space. Similar methods are followed with other crops in many regions.

Intercropping is frequently practiced in new asparagus beds and in fruit plantings of various kinds. This kind of intercropping is not objectionable if the welfare of the perennial plants is not jeopardized by poor management. In general, small-growing plants should be used as intercrops in the asparagus bed and in plantations of small fruit. The grower should, at all times, consider the welfare of his perennial plants and not allow the immediate money crop to interfere with their growth. The fertilizer applied should be sufficient to care for the needs of both the intercrop and the perennial crop.

CHAPTER XIII

CONTROL OF DISEASES AND INSECTS

Knowledge of control measures for important disease and insect pests is fundamental to successful vegetable growing at the present time. Both diseases and insects are becoming more serious due to the more intensive methods of gardening and the bringing in of new pests from foreign countries. No subjects taught in agricultural colleges are more important for the student interested in vegetable growing than entomology and plant pathology. Not only should the student learn the methods of control but he should be able to recognize common insects and diseases in the field. Essential points in the life history of common organisms should be known in order that control measures may be applied intelligently.

Since practically all agricultural colleges are giving fundamental courses in entomology and plant pathology these subjects are considered here only in their general relation to vegetable production.

Importance of Controlling Pests.—Insects and plant diseases cause losses to the vegetable growers of the United States running into many millions of dollars annually, probably into the hundreds of millions. Exact estimates are impossible because there are so many factors involved. To estimate the percentage of crops destroyed and then figure the monetary loss at the average price received for the portion saved is entirely misleading, because a reduction in total yield nearly always has the effect of increasing the price. In other words, a short crop often brings a greater total return, as well as a larger net return, than a very large yield. However, if insects and diseases did not have to be considered, vegetable growers could more accurately plan their plantings to meet the consumers' needs. They now make allowances for probable losses due to insects and diseases, and when these pests do not cause so great damage as expected there is usually a large yield, and this results in low prices. If, on the other hand, the losses are greater than normal the crop yields are low and this results in high prices to the consumer. In the long run the losses due to insects and diseases must be borne by society. The cost of production is greatly increased by diseases and insects because of the reduced yield due to their ravages. The expense of control measures practiced also adds to the cost to the consumer. With some vegetable crops the treatment for diseases and insects is one of the largest items in the cost of production. This item alone adds millions of dollars each year to the cost of food. There is also loss due to reduction in quality, for vegetables that are badly injured by insects and diseases are inferior to those that are not injured.

Up-to-date vegetable growers recognize that in many instances spraying, dusting, and other control measures are just as essential as cultivation or any other operation. It is impossible to produce satisfactory crops of certain vegetables in many regions without measures being taken to control diseases or insects or both. Even when diseases are not so serious as to be very evident on casual inspection it has been found that spraying or other treatment has in many instances greatly increased the yield. Instances are on record where the yield of celery was increased by 60 crates per acre by spraying for blight, although the growers stated that their crops were not affected. Onion yields have been increased 200 to 400 bushels per acre through smut treatment where the growers claimed that their crops were not seriously injured by this disease. Many other illustrations might be given but these show the importance of knowing what injury is being done by diseases and insects. Wherever crops are being injured by pests it is desirable to try out control measures to see if the value of the products is sufficiently increased to justify the expense of the treatments given.

Methods of Control.—Among the means for controlling insects and diseases the following are important:

1. *Rotation of Crops.*—The importance of crop rotation in insect and disease control is discussed in Chap. XII.

2. *Destruction of Refuse Harboring Diseases and Insects.*—Insects of many kinds pass the winter in the refuse left on the field or garden. If this is plowed under most of the insects will perish, but diseases that live over winter on the plant remains will not be destroyed by plowing. Some insects also pass the winter in weeds and trash in the fence rows and around the edges of the field; therefore cleaning up these places is of importance.

3. *Fall Plowing.*—In regions where severe freezing occurs many insects are destroyed by exposing the larvae or hibernating adults to the weather by plowing the land in the fall. The exposure to changing weather conditions even without severe freezing destroys many insects which pass the winter in the soil. The diseases caused by the nematode, an animal parasite, is not serious in the gardens of the North (but is a pest in greenhouses) because the severe freezing of the soil kills the parasite.

4. *Destruction of Affected Plants.*—This is an aid in the control of some diseases, such as bacterial wilt of cucumber and melons, by preventing the spread of the disease. Destruction of insects that feed on the plants is also important since they spread the disease.

5. *Abandoning for Two or Three Years Any Crop Badly Affected by Pests.*—This may be cheaper and quicker than to try to destroy the pest. Club root of cabbage and cauliflower can be controlled in this way provided no crop affected by this disease is grown on the land for two or three years.

6. *Protecting Plants by Mechanical Means to Prevent Insect Ravages.*—The most common method is to exclude the insect by screening the plant or seedbed. Individual plants and hills of cucumbers and melons are often covered with cheesecloth tacked on a frame or with a cone-shaped screen made of wire netting to protect the crop against injury by the cucumber beetle. Screening the late cabbage seedbed with cheesecloth prevents injury by the cabbage maggot. The screen prevents the fly from depositing eggs on the seedlings or on the soil.

7. *Use of Trap Crops in Controlling Insects.*—The harlequin cabbage-bug can be kept in check by planting kale, mustard, or rape so that the plants will be available to the insects before the desired crop is up. The bugs will congregate on the trap crops where they may be killed by spraying with pure kerosene. In the fall a few plants of turnips, cabbage, or kale left in the field after the main portion of the crop has been harvested, will attract the bugs which may be killed before going into hibernation.

8. *Seed Treatment to Control Diseases and Insects.*—Corrosive sublimate (bichloride of mercury) and formaldehyde have been used for many years for treating seed potatoes and, to some extent, for treating some vegetable seeds for certain diseases. These treatments are still used, but in recent years there has been a marked development in seed treatment with fungicidal dusts and with solutions of fungicides. Hot-water treatment is used also for the seeds of cabbage, cauliflower, Brussels sprouts, kale, turnip, and other crucifers, for the control of black rot, blackleg, and Alternaria leaf spot of these plants.

In the hot-water treatment, the seed is put in small cheesecloth bags and these are placed in a vessel of water held at 122°F. (50°C.) for 25 minutes for cabbage and 15 minutes for the other crucifers. Where a considerable quantity of seed is to be treated, a large vessel should be used in order to have a large volume of water. The water should be stirred constantly and the temperature determined with a good thermometer. When the temperature begins to drop, a small quantity of boiling water is added to keep the temperature constant. At the end of the treatment the bags are removed, dipped in cold water, and the seed spread out to dry. This treatment reduces the germination considerably, especially if the seed is old. It is desirable to test the seed for germination before treating and if germination is very low the treatment may ruin it.

Red copper oxide dust is used as a seed treatment for damping-off of crucifers, cucumber, muskmelon, squash, pumpkin, beet, eggplant, lettuce, pepper, salsify, spinach, peas, and tomato. The seed is placed in a tight container and sufficient of the dust is added to coat thoroughly the seed with the dust. The container is shaken to mix the dust and seed thoroughly and the surplus dust is screened out. The quantity of dust required per pound of seed varies considerably depending on the size and specific gravity of the seed. For seed of most of the crucifers 2 level teaspoonfuls of dust to a pound of seed is recommended; for seed of beet, eggplant, lettuce, pepper, salsify, spinach, and tomato, one teaspoonful is sufficient; for cucumber, muskmelon, squash, and pumpkin, one-half teaspoonful is enough for one pound of seed.

Corrosive sublimate is used for treating seed of cucumber, muskmelon, squash, and pumpkin for scab and angular leaf spot. It is also used for celery seed, less than two years old, to aid in control of early and late blight. Celery seed more than two years old does not need treatment as the organisms do not live more than two years. One corrosive sublimate tablet to one pint of water or one ounce of powder to 7½ gallons of water is the usual recommendation and for seeds of the cucurbits mentioned soaking for 5 minutes is sufficient; but for celery, soaking for 15 minutes is recommended. The seed is rinsed in water and allowed to dry before planting.

Calomel is used as a seed treatment for damping-off and for wire stem of crucifers, and for damping-off of celery. For celery seed one ounce of calomel is mixed thoroughly with one gallon of water. The seed is placed in tightly woven cloth sacks and dipped until the seeds are thoroughly wet. After treatment, the seed should be thoroughly rinsed in running water or in several changes of fresh water; even then considerable injury may result.

Copper sulphate solution may be used for treating seed of beets, eggplant, lettuce, pepper, salsify, spinach, and tomato, for damping-off, and for some of the seed-borne diseases of tomatoes. The seeds to be treated are put in cheesecloth sacks and soaked for one hour in a solution made by dissolving two ounces of copper sulphate in one gallon of water. The seed is dried before planting.

Semesan and Semesan Jr. are used as seed treatments to aid in the control of damping-off of crucifers, onions (where grown on upland soils), peas, and sweet corn. No specific directions can be given for the use of these materials except to follow the directions printed on the containers.

The choice of method of seed treatment for specific diseases of crops for which the treatments are recommended are discussed in the chapters dealing with crops.

It should be borne in mind that seed treatment is of little avail with many of these diseases if the soil, in which the seeds or plants are to be planted, is badly infested with the organisms causing the disease.

Bean and pea weevils can be kept under control by treating the dry seed with carbon disulphide. To be most effective the treatment must be made in the fall soon after harvest since the insects develop in the dry seeds.

9. *Soil Sterilization.*—Diseases in plant beds and in vegetable forcing houses are kept under control by sterilizing the soil with steam or formalin. Steam, when properly used, kills insects and weed seeds in the soil as well as diseases. The methods commonly used are the steam box, the inverted pan, and the perforated pipe. Soil for seed flats is often sterilized in a steam box, but this method is not very practicable where a large quantity is to be treated. By the inverted pan method a large galvanized pan (6 by 10 feet) about 6 inches deep is pressed down over the soil to be sterilized. The pan is connected to a steam boiler by means of pipe or rubber hose. In the perforated pipe method 1¼- or 1½-inch pipe, with ¼-inch holes on the under side at intervals of 12 inches is placed in the soil 8 to 12 inches deep. The lines of pipes should be about 18 inches apart and connected to a steam boiler. The soil should be heated to near the boiling point and kept there for 1 to 2 hours. A few potatoes placed on the surface of the soil will indicate the thoroughness of the treatment. When the potatoes are cooked the soil is well sterilized.

A method of soil treatment by electricity, termed pasteurization by Horsfall (1935), has come into use in recent years and seems to be satisfactory for soil to be used in seed flats and greenhouse benches where seedlings are to be grown. The soil to be treated is placed in a tight, well insulated box heated by carefully spaced electric heating elements covered with aluminum fins to dissipate the heat into the soil. Horsfall states that results obtained in his studies indicate that it would be safe with the one-cubic-yard outfit he used to heat the soil at a point midway between the upper heaters to 105°F. or higher before turning off the current. This required between 3 and 4 hours. The soil is left in the pasteurizer overnight to allow the heat to continue to act on the soil.

Formaldehyde is used for sterilizing seedbeds and plant beds. There is considerable variation in recommendations made for the use of formaldehyde, but most research workers agree on the formula of one part formaldehyde (40% strength) to 100 parts water, or 1:50. At the weaker strength one gallon of solution is recommended for each square foot of soil surface and at the higher concentration one-half gallon to each square foot of surface is advised. The object is to saturate the soil to the depth of 6 to 8 inches. If the soil is compact it is desirable to dig it up before applying the solution. After the solution has been applied, the bed should be covered with paper, burlap, canvas, or other materials for 24 to 36 hours in order to confine the gas. After this the covering should be removed and the soil aerated for a period of 10 days before planting seed or setting plants. If seeds or plants are planted too soon after the treatment is given, injury is likely to result. Sterilizing the soil with formaldehyde is cheaper than removing the soil and bringing in new uninfected soil.

Under some conditions plants do not grow well following sterilization of the soil with steam or with chemicals. The injurious effect of the process has been attributed to greater destruction of beneficial organisms than of injurious soil organisms; to accumulation of soluble salts in quantities toxic to plants; and to the puddling of the soil by the sterilizing treatment.

10. *Fumigation.*—This is a common method of controlling insects in the greenhouse. Various kinds of tobacco preparations, sulphur, and hydrocyanic acid gas are the most common fumigants. The last mentioned is a deadly poison which will kill all kinds of animal life; therefore it should be used with the utmost care.

11. *Use of Repellents.*—Plants are sometimes protected from insect injury by means of materials which repel the pests. Slaked lime, dry ashes, dust, and other similar substances are often used to repel cucumber beetles. Bordeaux mixture is used for protecting plants against flea beetles, the foliage being thoroughly coated with the material. The repellents do not destroy the insects, but prevent them from attacking the plants.

12. *Hand Picking Insects.*—This is a practicable method for the control of tomato worms, squash bugs, and blister beetles in home gardens or on small areas.

13. *Growing Resistant Varieties.*—In the control of some plant diseases the growing of resistant varieties is the most practicable means of control. In fact, in some cases, this is the only feasible means of controlling certain diseases such as the asparagus rust, Fusarium wilt of tomatoes, anthracnose of beans, cabbage yellows, and spinach blight (yellows and mosaic). Great progress has been made during recent years in developing strains and varieties of various crops resistant to specific serious diseases. Among the notable examples of resistant varieties the following should be mentioned: (1) Mary Washington and Martha Washington varieties of asparagus resistant to the asparagus rust, (2) Hollander and other varieties of cabbage resistant to the yellows, (3) Marglobe, Pritchard, Break O'Day, and other varieties of tomatoes resistant to the Fusarium wilt, (4) Well's Red Kidney, White Imperial, Perry Marrow, and Michigan Robust Pea beans resistant to the bean

anthracnose, and (5) Virginia Savoy spinach resistant to the blight, yellows, or mosaic. Breeding and selecting for disease resistance comprise one of the most promising fields for the plant breeder and the plant pathologist.

14. *Killing Insects and Preventing Disease Injury by Spraying and Dusting.*—Insects are classified into two classes: (1) chewing or biting forms which devour the leaves and other parts of the plants, and (2) sucking insects which injure and destroy plants by sucking their juices. For the former stomach poisons generally are employed as insecticides, arsenicals being the most common. However, some of the chewing insects are killed by contact with insecticides and by fumigants. Sucking insects cannot be killed by stomach poisons as they do not eat the surface that contains the poison. For such pests some insecticide that kills by contact or by the fumes being inhaled must be used. Kerosene emulsion and various dusts and sprays containing nicotine are the most popular insecticides for these.

Many fungous diseases are controlled by spraying or dusting the plants with material poisonous to the fungus, but harmless to the plant. Some bacterial and some virus diseases are controlled by destroying or repelling insects which harbor or carry infection. Plant lice and other insects carry the virus of mosaic diseases and the cucumber beetle is known to be the carrier of bacteria causing bacterial wilt of cucumbers and of other cucurbits. In the case of the bacterial wilt of cucumber, the bacteria are dependent on the cucumber beetle for aid in the life cycle.

In spraying or dusting for disease control, the material should be applied before the disease appears, or at least before it has gained much of a foothold, for most treatments prevent the development and spread rather than destroy it after it is established. The use of fungicides is more a preventative than a curative measure. Spraying or dusting before a rain is preferable to applying the material after a rain since the spores germinate best under moist conditions. If the fungicide is applied after a rain it may be too late to control the disease. Of course, spray material should be applied far enough in advance to allow it to dry before rains.

Timeliness and Thoroughness.—In all insect- and disease-control measures, timeliness and thoroughness are important considerations. For instance the fungicide should be applied before the appearance of the diseases or at least as soon as there is the slightest evidence. It is too late to control diseases after they have seriously injured the crops. Even for insect control, treatment is most effective when the material is applied as soon as the insects make their appearance. If the treatment is delayed too long the plants may be seriously injured or killed before the insects are destroyed. This is especially true where there is a heavy infestation, as there may be so many insects present as to do considerable damage before getting enough poison to kill them.

Since insects are killed mainly by eating the poison, or by coming into contact with the insecticide, and since disease spores are killed by contact with the fungicide, it is important to cover all parts of the plants with the spray or dust. For the control of many diseases and insects the underside of leaves, as well as the upper side, should be covered. Spray materials should be applied as a fine mist so as to cover the surface without having the liquid collect in drops and run off. High pressure is necessary to get a fine mist. In order to get good distribution insecticides in the form of dusts should be finely divided.

Spraying and Dusting Equipment.—Various kinds and sizes of sprayers and dusters, from the small hand sprayers and blowers to the large power machines, are in use. The small sprayers are not so efficient or so economical as the larger ones so that commercial gardeners should use the largest one that is practicable for the acreage to be sprayed. Under most conditions nothing smaller than the barrel sprayer should be purchased by the commercial vegetable grower. Where the acreage is large enough to justify the expense, power sprayers should be used as it is difficult to keep up sufficient pressure with the machines run by hand. Some power sprayers get their power from gearing the pump to the axle of the sprayer, while others are equipped with gasoline engines. Where high pressure is important the engine-driven pump is preferred. Small dusters compare more favorably in efficiency with the power dusters than do the small sprayers with the large power sprayers. However, where considerable acreage is to be dusted a large duster will be found to be more economical than the hand-power type.

Insecticides.—There are four general types of insecticides: stomach poisons, such as the arsenicals; contact poisons, as kerosene emulsion and the various oil sprays; fumigants such as carbon disulphide, hydrocyanic acid gas, nicotine fumes; and repellents which do not kill the pests but merely repel them. Among the stomach poisons the arsenicals, such as arsenate of lead, arsenate of calcium, and arsenate of magnesium are the most common. Arsenicals should not be used on vegetables when there is danger of residues remaining on the edible portions of the plants at harvest. They may be used on cabbage, cauliflower, and similar plants during the early stage of growth but when the heads begin to form other materials that do not leave poisonous residues should be used. One of the newer insecticides is rotenone, the chief source of which is derris and cubé root. Preparations containing rotenone may be used on vegetables without danger to man and, for this reason, rotenone dusts and sprays have become very popular in recent years. Hellebore, an insecticide made from the root of the hellebore plant, and pyrethrum, prepared from the flower of a plant of the same name, are also used to some extent where it is unsafe to use arsenicals.

Arsenicals.—Arsenate of lead is the most effective of the arsenicals and may be used on most vegetables crops, but it is more likely to injure the foliage than is either calcium arsenate or magnesium arsenate. These materials may be used either as a dust or as a liquid spray. As a spray, the arsenicals may be used with Bordeaux mixture or with nicotine sulphate solutions without impairing the effectiveness of either. As a dust, the powdered form of the arsenical is mixed with hydrated lime or other finely divided dry material in varying proportions depending on the kinds of plant to be dusted. To be most effective the dust should be applied when the foliage is moist and the air movement slight.

Prepared dust containing arsenicals and lime; arsenicals, lime, and copper sulphate, and various other combinations are available on the market and these are used on a large scale.

Rotenone-bearing Insecticides.—The chief source of rotenone is derris and cubé root. The strength of rotenone preparations is indicated by the proportion of rotenone they contain, although this is only an approximation because some of the other ingredients have insecticidal value. The percentage of the total active ingredients is usually indicated. Insecticides containing rotenone are available as extracts and dusts. Extracts from derris, cubé, or other materials that contain known percentages of rotenone are sold under various names. They may contain pyrethrins in varying quantities, equal to or slightly in excess of the rotenone content.

Rotenone dusts are prepared from powdered derris or related roots, and contain other organic substances, in addition to rotenone, that are toxic to many insects. Talc is one of the cheapest and most satisfactory diluents, but other materials such as diatomaceous earth, finely ground tobacco stems, and sulphur may be used. The dusts can be purchased ready mixed.

Pyrethrum.—This insecticide is prepared from the flowers of the pyrethrum plant. The insecticidal properties of pyrethrum preparations are dependent on the presence of two organic poisons known as pyrethrins. Insecticides made from pyrethrum are sold in two forms: extracts and dusts. Most of the extracts are rather expensive. Pyrethrum dusts are of two kinds, the ground flowers diluted with talc or other carriers, and those made by combining pyrethrum extracts with certain carriers. Experimental results indicate that the impregnated dusts are superior to that of the ground-flower dust in the control of such insects as the cabbage looper and zebra caterpillar.

Tobacco Preparations.—Nicotine, the poisonous principle of tobacco, is an alkaloid that seems to kill insects through the action of the vapors on the nervous system. It is thought that the vapors pass into the tracheae and from there reach the nerves and eventually cause complete paralysis. Tobacco dust and various decoctions have been used for a long time for the control of plant lice and other sucking insects. The ground stems and leaves often are used as a dust against plant lice. Tobacco stems are used to some extent for fumigating greenhouses. The stems are soaked in water and then burned forming a smudge giving off fumes of nicotine which kill the insects.

Commercial extracts of tobacco are now available in commercial quantities and these generally are preferable to the tobacco as they contain known quantities of nicotine. There are two classes of nicotine extracts, one known as free nicotine and the other as nicotine sulphate. Various materials used in the manufacture of insecticide dusts have different effects on the volatilization, others are inert and have no effect on the nicotine other than to expose large surface for its evaporation, while still others are active in that they change nicotine sulphate into more volatile forms.

When the nicotine sulphate is used alone it is recommended that soap, at the rate of 4 to 5 pounds to each 100 gallons of water be added to increase its spreading power, and to aid in liberating the nicotine. When used as dusts 2 or 3 per cent nicotine is satisfactory. Usually 20 to 40 pounds of the dust are applied per acre, the quantity depending on the size of the plants or the foliage surface to be covered.

Fungicides.—The term fungicide is applied to any material used to control fungous diseases. Bordeaux mixture is the most common fungicide used in controlling diseases of vegetables, but others, such as sulphur, corrosive sublimate, and formalin are used to some extent. Corrosive sublimate and formalin are used mainly as disinfectants for soil and seeds, although the former is known to have some effect on club root of cabbage and other crucifers.

Bordeaux Mixture.—This mixture is made of copper sulphate, lime, and water. A common formula is 4–4–50, meaning 4 pounds of copper sulphate, 4 pounds of lime, and 50 gallons of water. Some crops, such as cucumbers and muskmelons, seem to be injured by lime and some authorities recommend a 4–2–50 formula for use on these two crops.

Where bordeaux mixture is to be used in large quantities it is desirable to make up stock solutions of copper sulphate and of lime. A stock solution of copper sulphate may be made by dissolving 50 pounds of copper sulphate crystals in 50 gallons of water. Crystals placed in a gunny sack and suspended in the top of the barrel or tank of water will dissolve in 3 or 4 hours. A stock lime mixture may be made by mixing 25 or 50 pounds of lime, either hydrated or slaked burned lime, in 50 gallons of water. Some authorities prefer slaked burned lime but hydrated lime is used by many with apparent success. Air-slaked lime or hydrated lime that has been partly air-slaked should not be used.

COPPER-LIME DUST.—Within recent years copper-lime dusts have been used to a considerable extent in some sections in the control of certain diseases. There is considerable difference of opinion among authorities on the relative effectiveness of liquid Bordeaux and dry Bordeaux for the control of various diseases. Results of some experiments have shown practically as good control with the dry as with the liquid, while others have shown the liquid spray to be more efficient.

Where vegetables are grown on a small scale, as in the home garden, the use of dust is more practicable than is spraying. In fact for many diseases it is probable that dusting is as effective as spraying where other than power sprayers are used. In other words, where the acreage of crops does not justify the investment in a power sprayer, dusting is a good substitute for spraying.

Dusting has some advantages over spraying. The main advantages are: (1) the loaded machine is lighter and easier to operate than is the sprayer, since no water is needed in dusting, (2) the cost of applying is less since a greater acreage can be covered in a day with a dusting machine than with a sprayer, (3) the duster can be operated on hilly land where a sprayer could not be used, (4) there are fewer delays since there are no nozzles to clog and no hose on the duster to burst. Where there is no available water supply near at hand the dusting machine is more practicable than the sprayer, since the cost of hauling water considerable distances is almost prohibitive.

Dusting, however, has its drawbacks. The main disadvantages in the use of dust are: (1) dust is less effective than liquid sprays in the control of some diseases and some insects, (2) the dust cannot be applied successfully when there is much wind and in many instances this limits the time of application to short periods during the day, mainly in the late afternoon and early evening and early in the morning. In some cases it is necessary to run the machine at night in order to apply the material when needed. The cost of dust is greater than the cost of spray materials for the same acreage of crops protected, but, of course, this may be offset by the lower cost of application. Improvements are being made which increase the effectiveness of the dust and the efficiency of the machines.

CORROSIVE SUBLIMATE (mercuric chloride).—Corrosive sublimate, 1 part to 800 or 1,000 parts of water, is an effective disinfectant for potato and sweet potato seed as well as for seeds of other crops. It is also effective in the control of the cabbage maggot. Weaker solutions are used in treating some seeds which are injured by the 1 to 1,000 strength solution. Corrosive sublimate is a deadly poison and should be used with the greatest of care. It corrodes metal, therefore, only wooden or earthenware receptacles should be used to keep it in for any considerable length of time.

General Crop Diseases.—Among the more serious diseases that are rather general, the most important are root knot, caused by a parasitic eelworm or nematode; Rhizoctonia which causes cankers on the stems and roots of various plants; and damping-off. Root knot is discussed in connection with cabbage, and Rhizoctonia is described in connection with the potato.

Damping-off is often serious on plants in the seedbed and transplanting bed. The plants are attacked at or near the surface of the ground causing a rotting or "damping-off." This may be caused by any one of several species of fungi including Pythium, Rhizoctonia, Botrytis, Sclerotinia, Phoma, Phytophthora, Colletotrichum, and Gloeosporium.

Since the growth of these fungi is favored by moisture and relatively high temperature, the trouble may be checked by keeping the temperature down and withholding water. It is especially important to water the plants in the bed early in the day so that the plants themselves and the surface of the soil may dry before night. Thorough ventilation of the greenhouse, hotbed, and cold frame is important.

Sterilizing the soil used for the plant bed and treating the seed are recommended.

General Crop Insects.—Insects may be grouped roughly into two classes, from the standpoint of their food plants: (1) those that ordinarily attack only a single crop, or a few closely related crops, and (2) those that are general feeders and are not particular as to their food plants. Examples of the first class are asparagus beetles, potato beetles, and the large tomato worm, the last two feeding on a few closely related plants. The second class includes cutworms, white grubs, wireworms, blister beetles, grasshoppers, onion thrips, and red spider.

The onion thrips is usually most injurious to the onion crop although it attacks cauliflower, cabbage, cucumbers, tomatoes, turnips, and kale. This insect is discussed in connection with the onion crop. The other insects are discussed here because they are equally destructive to a number of crops.

Cutworms.—Cutworms are nearly smooth caterpillars 1 to 2 inches long, the larvae of large-bodied moths. Many species have been reported as pests of vegetable plants. Their greatest injury is done by cutting off the stems of young plants near the surface of the ground, especially of those plants which are transplanted and are spaced considerable distances apart, as cabbage, cauliflower, tomato, eggplant, and sweet potato. Cutworms work mainly at night and one worm can destroy many plants in a single night.

The best method of control is the use of poisoned baits. A common bait is made with the following materials:

Bran	20 pounds
Arsenate of lead powder	1 pound
Molasses	2 quarts
Oranges or lemons	3 fruits
Water	4 gallons

Another bait recommended is made as follows:

Dry bran	25 pounds
White arsenic or Paris green	1 pound
Sirup or molasses	2 quarts
Water	15 to 20 quarts

The dry materials are mixed thoroughly in a tub or other receptacle. The juice of the oranges or lemons is squeezed into the water and the molasses is also mixed with the water, then a mash is made. After the mash has stood for a few hours, it is scattered over the field in small lumps. It should be put out late in the day so that it will not dry out before night. The bait should not be used where there is danger of chickens getting it.

Clean cultural methods and fall plowing also aid in controlling these worms.

White Grubs.—These are the larvae of May beetles or June beetles (*Lachnosterna arcuata*). They feed chiefly on the roots or other underground portions of plants and are often injurious to corn, potatoes, and strawberries; but they are general feeders. Grubs are usually most injurious to crops following sod.

A short rotation in which sod is left not more than two years is advised. Clean culture and plowing in the fall aid in the control of this pest. Hogs and chickens, if allowed the run of newly plowed land, destroy large numbers of the grubs. Where they are abundant in sod land it is best not to use it for potatoes or sweet corn.

Wireworms.—Wireworms are the larvae of click beetles. They are long, hard-shelled, brownish larvae often abundant in sod land. They are injurious to the roots and other underground portions of plants, especially to potatoes, carrots, beets, sweet potatoes, and onions.

The remedies advised for white grubs apply to wireworms, but these worms are much more difficult to control.

Grasshoppers.—These insects are troublesome to vegetables, especially in the dry regions of the Middle West. The poisoned bait recommended for cutworms is one of the best remedies for grasshoppers.

Blister Beetles.—These insects are common garden pests and are often destructive to beans, peas, potatoes, and beets, although they feed on many kinds of plants. The beetles are slender, somewhat soft bodied and variously colored. They are injurious in the adult stage and are difficult to control.

Spraying with arsenicals when the beetles first appear is the best control.

RED SPIDER.—The red spider (*Tetranychus telarius*) is not a true spider but a mite. It is well distributed and is often injurious on beans of all kinds, eggplant, cucumbers and other cucurbits, tomatoes, beets, and celery. It is a serious greenhouse pest. It is often present on the underside of leaves without being suspected. It injures the plants by sucking the juices. When it is abundant, leaves lose their color, shrivel, and die.

Spraying with "Black Leaf 40" or other nicotine preparation is the best remedy for red spider in the open. In the greenhouse, spraying the plants with water under pressure will reduce the number of red spiders, and is the method of control commonly employed.

CHAPTER XIV

MARKETING

Profits in commercial gardening depend as much on proper handling and marketing as on good cultural practices. Many gardeners, however, assume that when they have produced crops of good quality and put them on the market they are not to blame if the receipts do not cover the cost of growing. The grower is largely responsible for the appearance of his product when it reaches the market, and, unless he has carefully graded and packed it in attractive, substantial packages, he has not done all that is expected of him. The essentials for success in profitable marketing are: (1) a good, seasonable product, (2) careful and uniform grading, (3) good packing, (4) attractive packages of convenient size and shape, (5) judicious selection of markets to avoid gluts, (6) honesty in grading and packing and in all dealings with the buyer, and (7) good salesmanship.

Many gardeners are experts as producers and failures as salesmen. This is natural since the problems are different, but it is essential that the grower, who does his own marketing, devote time and study to the problems of marketing as well as to those of production. Under many conditions it is probably better for the grower to specialize on production and let others do the marketing than to attempt to become expert in both lines. However, the grower must know what the market demands both in products and methods of handling, even if others are looking after the selling.

Much of the marketing problem belongs to the field of economics, hence most of the discussion here deals with the product itself and with the physical handling of it. To understand the problems of transportation, of organization of marketing agencies, of distribution, of factors affecting marketing costs, and of merchandizing requires a knowledge of the fundamentals of economics. It is probable, however, that the greatest opportunity for improvement in the quality of the product is through the use of better strains and varieties, through better production, harvesting, grading, packing, and other handling methods. The grower is responsible for the marketability and quality of the product as it leaves his hands and the improvement that can be made up to this point largely is dependent on his own efforts. While it may be true that the cost of distribution of perishables in the large cities is too high, there is little the individual grower can do about it. The grower can improve the grading, packing, storage, and loading of his produce, and this improvement would go a long way toward solving some of the problems of marketing.

The harvesting, grading, packing, and handling methods for the various products are discussed under the individual crops.

Harvesting.—The stage of development of vegetables when harvested determines to a considerable extent the quality of the product when it reaches the consumer. No definite rule can be given in regard to time of harvesting since this depends on the kind of crop, on the weather conditions at harvest time, and on the distance to market or the length of time required to reach the consumer. Such crops as beans, Lima beans, peas, sweet corn, etc., deteriorate in quality if not harvested soon after reaching edible maturity; therefore it is always advisable to harvest them as soon as this stage is reached. With products which increase considerably in size after reaching edible maturity there is a tendency to delay harvesting until they have reached full size. This delay often results in lowering the quality of the product, especially with beans, peas, Lima beans, beets, carrots, cucumbers, and sweet corn. Tomatoes and muskmelons grown for distant markets are harvested long before they reach edible maturity. In fact, in many cases they have not begun to ripen when harvested. This results in poor quality and has a decided tendency to depress the market for these products. Both tomatoes and muskmelons should be allowed to remain on the vines as long as possible and still have them reach the consumer in good condition.

Promptness is of great importance in harvesting and handling many perishable crops. A day's delay may result in heavy losses, especially in hot, sultry weather or in seasons when frosts are likely to occur. Lettuce often becomes almost worthless in a day after the heads have formed, especially if the weather is very hot. The plants may send up seed stalks or become seriously injured by "tip burn" and "drop." Promptness in removing the products from the field is important with most crops, especially in very hot weather and in wet weather.

Enormous losses occur each year due to carelessness in harvesting and handling vegetables. Much of this could be overcome through instruction of the help in the proper methods of harvesting and handling the products in the field. Bruising or other injury detracts from the appearance of the product and makes it more susceptible to disease injury since germs are more likely to get a foothold if the surface is broken.

Preparation for Market.—Many vegetables require special preparation before they are ready for packing. Root crops, asparagus, celery, lettuce, spinach, and other vegetables are often washed to remove any soil that adheres. While water is used mainly for the sake of cleanliness it has other values. It gives some vegetables a bright appearance and prevents them from wilting. Washing may be injurious, since moisture on the surface is favorable to the development of diseases, especially when the washed product is packed tightly and shipped considerable distances without refrigeration.

Some vegetables are trimmed in preparation for marketing. The dirty, decayed, diseased, and discolored leaves of celery, lettuce, spinach, and other leafy vegetables are removed before the products are packed for market. Removing diseased leaves is of value in checking the development of disease in transit and on the market, and also improves the appearance of the product. Ramsey and Markell (1917) found that removing lettuce leaves that rested on the soil reduced the loss due to the development and spread of lettuce drop (*Sclerotinia libertiana*) in transit. Part of the foliage of root crops and onions, when bunched for market, is removed either by stripping off part of the leaves or by cutting back all of them. In any trimming the aim should be to improve the appearance and otherwise increase the value of the product.

Asparagus, rhubarb, celery, green onions, early beets, and carrots are often tied in bunches in preparation for market. This is done for convenience in handling in retail stores. Various materials such as raffia, common wrapping cord, and special tape are used for tying. The bunches should be tied tightly so that they present a neat appearance on the market.

Grading.—Well-graded products of inferior quality often sell to better advantage than poorly graded or ungraded products of high quality. A few inferior specimens in a package govern, to a considerable extent, the price paid for the entire contents of the package. Uniformity in size, shape, color, and ripeness is of great importance in disposing of any product and this cannot be secured without careful grading. Grading means more than separation with reference to size, although this is important. In separating any product into grades all characters that affect the appearance and quality of the product should be considered.

Not only should vegetables be carefully graded, but there should be some recognized standard that applies to a region or preferably to the whole country. Uniform and well-recognized grades make for cheap marketing, for, if articles are not graded or are poorly graded the buyer has to inspect the product before he can know what he is buying. This adds to the cost. By dividing products into uniform grades, sales may be made by grade, thus facilitating the marketing process. Uniformity in grading is absolutely essential to success where products are sold on grade.

Standard grades furnish the basis for trade. Some standard is essential in marketing products at a distance, and also for market information and inspection. Lack of grade standards has made market quotations unsatisfactory to the grower because it has not been possible to describe products in terms that are understood. With standard grades the buyer and seller have a common language in the grade name or number. This is especially true if the grades are legalized by state or national laws. The purchaser of potatoes under the U. S. Potato Grading Law is reasonably sure that he will get a product that will meet at least the minimum requirement of the grade specified, and the grower is reasonably certain to obtain a price based on a definite grade. Standard grades eliminate a great deal of friction between producer and dealer due to lack of understanding and also reduces loss caused by rejections, delays, and dishonest dealing. They simplify the whole marketing process. Standardizing grades is one of the first improvements attempted by any successful cooperative marketing organization, for it is recognized that the first step in marketing is to have standard products.

During recent years the Department of Agriculture and some agency of most of the states have studied the methods of grading employed by producers and dealers with the idea of working out grades for various products. Tentative grade standards have been worked out by the Department of Agriculture for most of the important vegetable products. These grades are not compulsory, but if they are used and the package carries a statement of the grade name or number, the contents are expected to meet the grade requirements when shipped out of the state. Some of the states have adopted the federal grades for certain products and when these are packed according to the grade specifications the goods must meet the requirements in both intrastate and interstate commerce.

In any set of grade standards the aim should be to make the grading and the descriptive terms as simple as possible. Technical descriptions and complicated grades discourage the use of any set of standards by the average grower. The number of grades should be kept to the minimum, preferably only two for most products. The first grade should include a large part of any well-grown crop. The second grade should usually include the marketable product that does not meet the requirements for the first grade. If any portion of a crop is below the requirements of the second grade, and is still marketable, it should ordinarily be sold by sample as "sample grade."

Packages for Vegetables.—Packages of some kind are necessary for nearly all vegetables when they are shipped, and for most of them even when hauled direct to the market from the field. Packages perform the following functions: (1) furnish convenient means for hauling products, (2) give protection to the goods themselves, (3) furnish security from pilfering, (4) provide a measure of the contents, (5) provide ventilation, (6) prevent loss of small articles, (7) insure cleanliness, (8) provide a means whereby products may carry identification marks, shipping directions, legal requirements, and advertising matter.

Vegetables are packed in a great range of kinds and sizes of containers from the quart berry box to the barrel, including many kinds and sizes of baskets, hampers, boxes, crates, bags, and paper cartons. Some of the containers are employed for one kind of product only, as for example, celery crates, cantaloupe crates, cauliflower crates, and asparagus crates. Other kinds, such as the round stave basket, till baskets, handle baskets, hampers, lug boxes and bags are, more or less, general-purpose containers used for many kinds of products.

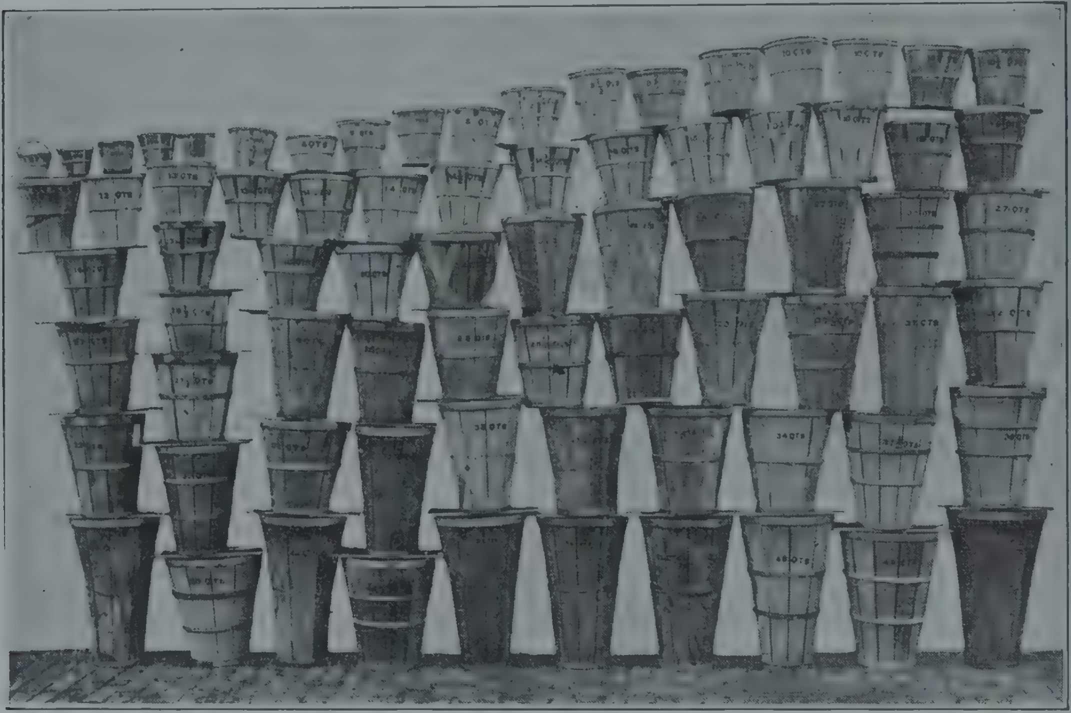

Fig. 13.—Seventy-five types and sizes of hampers in use in the United States in 1920. Compare with Fig. 14. (*Courtesy of U. S. Dept. Agr.*)

During recent years, considerable progress has been made in standardizing the sizes of some of the containers used (Figs. 13 and 14). Downing and Spillman (1924) reported that 50 styles and sizes of hampers were in use in the United States, but since that time hampers have been standardized by federal statute and only six sizes are legal. The standard sizes are $\frac{1}{4}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1, and $1\frac{1}{2}$ bushels. Five sizes of hampers that meet the federal standard are shown in Fig. 14. Other standardized containers for fruits and vegetables are the standard barrel, capacity 7,056 cubic inches, and its subdivisions; the cranberry barrel, 5,826 cubic inches, with its subdivision; climax baskets of three sizes, 2, 4, and 12 quarts, dry measure; and standard berry boxes and till baskets, capacity $\frac{1}{2}$ pint, 1 pint, 1 quart, and multiples of the quart, dry measure. Some of the states have standardized various kinds of containers: California has standardized lettuce and cantaloupe crates; Illinois has standardized the barrel, and containers less than one bushel capacity; New York has standardized the barrel, the old type lettuce crate used for Big Boston lettuce, and the celery crate. Other states have laws regulating the sizes of containers of various kinds.

There is still need for standardization of containers and the elimination of many sizes. Cabbage crates, celery crates, cauliflower crates, asparagus crates should be standardized so that only a few sizes and types would be in use for each type of product. The large number of sizes and kinds of containers in use leads to confusion and adds to the cost of the product to the consumer by increasing the machinery necessary for manufacture.

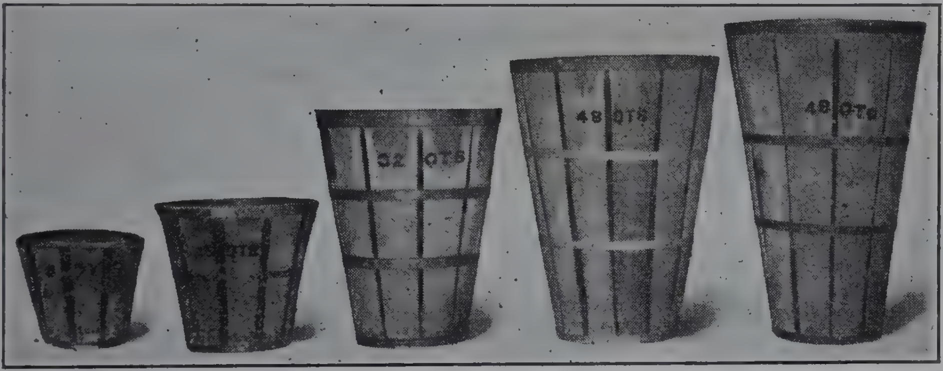

Fig. 14.—Five hampers of sizes and types recommended by the U. S. Department of Agriculture, as meeting all the requirements of the trade. Compare with Fig. 13. (*Courtesy of U. S. Dept. Agr.*)

The Standard Barrel Act is enforced by the Bureau of Standards, Department of Commerce, and by local sealers of weights and measures in those states which have adopted the federal standard. The United States Standard Container Act, fixing standards for climax baskets and for berry boxes, small till baskets, and hampers is enforced by the U. S. Department of Agriculture.

There appears to be a trend toward smaller containers for many products. This is indicated by the use of "pony" crates for cantaloupes and celery; 8- and 12-quart climax baskets for tomatoes and other products; 100-pound sacks for potatoes in place of the 150- and 180-pound sacks formerly used; and 50-pound sacks for onions in place of the 100-pound sacks. Consumer-size containers are increasing in importance also. These include special paper bags and cloth bags used for potatoes and holding from 5 to 50 pounds, mesh bags for onions holding from 5 to 25 pounds, and various sizes and kinds of cartons used for celery, rhubarb, tomatoes, and other products.

Packing Vegetables for Market.—In packing vegetables for market there are three important considerations: (1) a satisfactory package for the product, (2) honest packing, which includes uniform product throughout the package and full measure, (3) careful placing of the product so that the specimens will remain in position until they reach the market and present an attractive appearance.

The package should be selected for the particular product, bearing in mind the protection of the product itself and also the demands of the market. In selecting a container for vegetables to be shipped long distances, attention should be given to its ability to withstand rough handling and to its desirability from the standpoint of stacking in the car, as well as to the possibility of quick cooling.

Honest packing should be practiced because "honesty is the best policy." The packer who puts up a dishonest pack fools no one but himself. The buyer is always on the lookout for dishonest packing and usually penalizes the produce and the producer, or packer. A few low-grade goods in a package of high-quality produce govern to a large extent the price paid for the entire contents.

Use of Paper in Vegetable Marketing.—Large quantities of paper of various kinds are used in the preparation of vegetables for market. Paper is used for wrapping many products, such as tomatoes, celery, asparagus, and others, before they are packed; it is used for lining packages for many products, such as lettuce, washed celery, bunched root crops, broccoli, and sweet potatoes. Paper is used for top sheets over the packaged products and for labels and stickers on individual fruits of muskmelons and on the packages of many vegetables.

The following advantages are claimed for paper wrappers, and the same claims might be made for paper liners: (1) keep the product clean and protect it from infection from the outside, (2) retard transpiration, evaporation, and wilting, (3) protect the product from bruising and other mechanical injury, (4) protect against rapid changes in temperature (may prevent injury from freezing), (5) improve appearance of product, and (6) provide means of carrying trademarks, advertisements, and information.

There are some objections to the use of paper for wrappers and package liners. McKay, Fischer, and Nelson (1922) stated that wrapping muskmelons delays refrigeration, discourages inspection, and increases decay. The wrappers keep the surface of the product moist and favor the development of decay. Some handlers claim that the paper may conceal defects and also may conceal the attractiveness of the product.

The kinds of paper used in vegetable marketing include tissue paper, waxed kraft, parchment and parchmentized kraft, and others. Tissue paper is used to wrap tomatoes and a few other products. Waxed, parchment, and parchment kraft papers are used to wrap celery, asparagus, and other products, and to line packages for celery, lettuce, bunched root crops, and many other kinds of vegetables. Brown (1928) stated that waxed papers limit ventilation and encourage rotting of vegetable products at high temperatures. He suggested that the greatest value of such paper is for the prevention of wilting of produce held in refrigerators. Parchment and parchmentized kraft are resistant to disintegration when wet and permit sufficient passage of air to prevent suboxidation of most products.

Paperboard is being used for baskets, small boxes, cartons, and other containers. Some small cartons are made with windows of cellulose film, and such film is used to some extent as covers and wraps for some vegetables.

Transportation of Vegetables.—Market-garden products are hauled direct to the market mainly by motor truck. The truck grower at a greater distance from the market transports his produce by truck, by express, by through freight, usually in carload lots, or by boat. The transportation problem of the truck grower is much more complicated than that of the market gardener and the transportation expense is usually much greater. For most products, shipped long distances, refrigeration must be used and this adds to the cost of transporting. During very cold weather, cars are often heated to prevent freezing. Both refrigeration and car heating are items of expense almost unknown to the market gardener.

Transportation facilities have extended the area of production of perishable products from the limits of the wagon haul to the confines of the United States and even beyond. Fast freight and the refrigerator car now enable producers, located long distances from the market, to take advantage of climatic conditions to grow crops for the large markets, when these markets could not be supplied with local products. This has the effect of extending the season of consumption of many crops. Most of the important vegetable crops are now available in the fresh condition practically throughout the year.

While most of the fresh produce marketed in the United States is shipped to market by truck or by rail, water transportation is still used to some extent. Some of the produce grown in Michigan is shipped by boat to Chicago, Milwaukee, and other lake ports; produce from Norfolk, Va., is shipped to Washington, Baltimore, New York, and Boston by boat. Water transportation is cheaper than rail transportation, but it usually takes longer than by rail or truck.

During recent years there has been a marked development of motor-truck transportation. According to Rasmussen (1938), in 1929 only 13 per cent of the fruit and vegetable supplies of New York City arrived by motor truck, whereas in 1936 the motor-truck shipments reached 34 per cent. During the same period the receipts of fruits and vegetables at New York City arriving by truck from nine near-by States—Connecticut, Massachusetts, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and North Carolina—rose from 42 per cent (1929) to 86 per cent (1936). It was estimated by the U. S. Bureau of Agricultural Economics that, in 1934, for the United States as a whole, 38 per cent of the shipments of fruits and vegetables moved to market by motor truck.

While transporting vegetables by motor truck 300, 400, 500 miles or more is not uncommon, a large percentage of the produce moved by truck is hauled less than 50 miles. Rasmussen (1937) reported that, on the average, 91 per cent of grower-owned trucks and 57 per cent of all hired trucks used for transporting vegetables to market, in the nine states mentioned above, were limited to hauls of not over 50 miles from the farm. Most of the hauling by or for growers was within a radius of 100 to 150 miles from the farm. Only 7 per cent of the tonnage shipped in hired trucks moved more than 300 miles. Analysis of haulings of 65 merchant truckers in nine states, reported by Rasmussen (1938), showed that about 11 per cent of the tonnage of fruits and vegetables was hauled 300 miles or more.

The use of the motor truck has made more difficult the problem of estimating the quantities and kinds of produce that will be available for sale on the important markets at any time. There is need for a system of reporting probable arrivals of produce by truck before the opening of the market each day. There is also need for truck terminal facilities in most large city markets.

Precooling of Vegetables.—When vegetables are harvested during hot weather it is desirable to remove field heat as quickly as is feasible in order to retard ripening and deterioration. This is accomplished with some vegetables by precooling either before they are loaded or immediately after. Some products are precooled by being immersed in ice-cold water or passed through a spray of cold water. These methods are satisfactory for celery, spinach, the root crops, and peas, but are not satisfactory for beans and Lima beans. Precooling can be accomplished by placing the products in a good cold storage room for several hours, provided there is forced circulation of air. Quick cooling will take place in a good refrigerator car equipped with basket bunkers that allow free air circulation around the ice. The use of salt with the ice hastens the cooling. Precooling is of little value unless the precooled produce is shipped under refrigeration. Where ice is placed in the package, as is done with lettuce, peas, bunched beets, carrots, and other root crops, cooling is accomplished in a comparatively short time.

Selling Vegetables.—Vegetables are disposed of by producers by many different methods, both at retail and at wholesale. Retail sales are made directly to the consumer through house to house calls, through city retail markets, and through roadside stands. Wholesale sales are made (1) to retail stores, restaurants, and hotels, (2) to country buyers and shippers, (3) to trucker dealers, at the farm and at city and regional markets, (4) to wholesale dealers and jobbers in the market, (5) through auction markets in the producing regions, and (6) through cooperative organizations of producers. The cooperative organization may use any or all of the wholesale selling methods mentioned. In addition to outright sales, producers may consign produce to merchants who sell on commission.

Retail selling is not popular with growers, except with those who have good locations for roadside markets. All retail methods of sale are expensive and most growers believe that their time is of more value on the farm than in selling produce in small lots to the consumer.

Market gardeners sell most of their produce at wholesale to retail stores, to various types of buyers on local markets in near-by cities or on regional markets. Growers who are located long distances from market sell largely to wholesale dealers or jobbers. These may be local buyers or representatives of buyers in distant markets who buy outright at the shipping point. Produce may be sold by wire subject to inspection on arrival, but most growers prefer to sell to buyers at the shipping point rather than to take chances subject to inspection on arrival.

Cooperative marketing by farmers has been employed to a limited extent for many years, but within the past 25 years hundreds of cooperative organizations have been formed for selling all kinds of agricultural products and for buying supplies. While these associations can accomplish more for the farmer than he can accomplish for himself it should be remembered that there have been many failures and relatively few successes in this field. This fact should be a warning to go slowly and to study thoroughly the need of a cooperative organization, the reasons for success and failure, and the methods followed by successful organizations. Many failures have been due to the fact that the growers did not see the need of a cooperative organization, to lack of cooperative spirit, to poor management, and to poor business methods.

Cooperative associations, to be successful, must be organized because of a real need and the members must have the proper attitude toward cooperation. In addition to these there must be a sufficient volume of business to make economical operation possible, there must be capable management, good business methods, and loyalty to the association on the part of the members.

Some of the important services that a cooperative organization can render to the grower are: (1) to standardize the product, (2) to improve the grading and packing, (3) to develop old markets and find new ones; (4) to effect savings through large-scale handling, better distribution, etc., (5) to obtain and disseminate crop and market information, (6) to advertise the products of the members and (7) to buy needed supplies. Most of these things can be accomplished by an organization because funds are available to obtain the services of experts along the various lines. This is impossible for most individual growers, since the volume of business is too small to bear the burden of all the services that a cooperative association can render.

Roadside Markets.—During recent years there has been a marked development in roadside marketing in the vicinity of practically all cities of any considerable size. These markets range in size from a soap box or a chair with a small quantity of one or two products to a large roadside store selling hundreds of dollars worth of fruits and vegetables per day.

DeVault and Bouis (1926) give the following as essentials in the operation of successful roadside markets:

1. Possession of a desirable location with adequate driveways and parking facilities to accommodate the public.
2. An adequate volume of business sufficient to justify the devoting of time and effort in operating the stand.
3. An attractive display of products that are sound, of uniform grade and quality, and put up in neat, appropriate-sized containers convenient to handle.
4. Succession of crops coming on the market throughout the season.
5. Good, suitable buildings with efficient help and accommodations for the convenience and pleasure of the customers.
6. Attractive surroundings.
7. Reasonable prices.
8. Neat appearance of operator and good sales ability.

In general, a roadside market should be located well off the edge of the road, preferably where the road is level, or at the top of a hill for motorists do not care to stop at the bottom of a hill. Of course the market should be located where it can be seen easily from the road some distance away. DeVault and Bouis found that a location on the right-hand side of the road leading into town sells much more produce than one located on the opposite side. This is due to the fact that most persons buy produce on returning from a drive and prefer not to have to cut through traffic to reach the stand. This is of particular importance on roads that have heavy traffic.

In Michigan a study of 80 roadside markets made by Gaston (1929) shows that stands located on the right-hand side of the road leading into town did over twice as much business (100 to 47) as those located on the opposite side. The purchases were larger when made as the buyer was returning home.

The question of price at which products should be sold at roadside markets is one on which there is considerable difference of opinion. In general, it would seem that the producer should get some of the profit usually taken by the wholesaler and retailer. On the other hand, the consumer should not be expected to pay so much for products at roadside markets as he would pay for the same grade and quality at city retail stores. Some students of roadside marketing suggest that the price the consumer pays should be above the wholesale price, but somewhat below the retail price, since there are no delivery charges and little loss of product. Eastman (1929) suggests a price 5 to 10 per cent below the city retail price for the same grade of product.

CHAPTER XV

STORAGE OF VEGETABLES

Storage of perishable products is an economic necessity and the business of storage is an important element in modern marketing of vegetables. Storage stabilizes prices by carrying over goods from periods of high production to periods of low production, thus, preventing gluts on the one hand and bare markets on the other. Without storage the producer would be forced to put his crops on the market soon after harvest, regardless of the demand. This would cause a glut and market stagnation with consequent loss to the producer. While the consumer would benefit by lower prices during a glut he would more than make up for this later in the season when the demand became greater than the supply, resulting in very high prices. Without storage enormous losses would occur due to deterioration and decay, and this would increase costs to the consumer without benefitting the producer.

The enormous increase in the winter production of vegetables in the South, in California, Mexico, Cuba, and elsewhere has had a marked effect on the stored product grown in the North. Potatoes, cabbage, celery, carrots, and onions produced in the northern states come into competition with the fresh product grown in the other regions mentioned above. This competition is increasing in severity and the tendency is toward a shorter storage period for northern-grown produce.

Specific storage requirements for the various products are discussed under the crops in Chaps. XVI to XXVII.

Requirements of Storage.—Successful storage of vegetables requires a good product to begin with, the proper moisture and temperature for the particular products to be stored. The product should not be overripe, in fact, many products keep best when harvested before they are fully matured. They should be practically free from disease and injury of all kinds. A diseased or injured product usually deteriorates rapidly in storage.

Specific rules regarding moisture and temperature that will apply to all products stored cannot be given. Such products as beets, carrots, parsnips, and turnips keep best in a relatively cold, moist atmosphere, while others, as onions, require a cold dry atmosphere for best results. Sweet potatoes and pumpkins keep best in a relatively warm, dry atmosphere and deteriorate rapidly under moist, cool conditions. Control of moisture and temperature are obtained in various types of storage structures by natural or by artificial means.

A summary of desirable storage conditions and maximum storage periods for various vegetables as reported by Platenius, Jamison, and Thompson (1934), is given in Table XVII. It should be kept in mind that the growing conditions, the stage of maturity, the variety of the vegetable, disease infection, and other factors affect the storage life of these products.

TABLE XVII.—RECOMMENDED STORAGE CONDITIONS AND APPROXIMATE MAXIMUM STORAGE PERIOD FOR VEGETABLES

Vegetable	Temperature, °F.	Relative humidity, per cent	Maximum storage period
Asparagus	32	95 to 98	1 week
Beans, Lima	32	90 to 95	2 to 3 weeks
Beans, snap	40	90 to 98	12 days
Beets	32 to 40	90 to 95	4 to 5 months
Broccoli, sprouting	32	95 to 98	10 days
Brussels sprouts	32	95 to 98	2 months
Cabbage	32 to 40	90 to 98	5 months
Carrots	32 to 40	90 to 95	6 months
Cauliflower	32	90 to 98	30 to 40 days
Celery	32	90 to 98	3 to 5 months
Cucumbers	32 to 40	95 to 98	4 to 5 weeks
Eggplants	32	90 to 95	3 to 4 weeks
Kale	32	95 to 98	1 month
Lettuce	32	95 to 98	3 to 4 weeks
Muskmelons, immature	50	80 to 90	2 weeks
Muskmelons, mature	32	80 to 90	1 month
Onion and onion sets	31 to 32	80 to 95	5 months
Parsnips	32	90 to 95	5 months
Peas, green	32	95 to 98	2 weeks
Peppers	32	95 to 98	40 days
Pumpkins	40	50 to 70	2 to 3 months
Rutabagas	32 to 40	90 to 95	3 to 4 months
Squash	40	50 to 70	5 months
Sweet corn	32	90 to 98	3 to 4 weeks
Tomatoes, green	50 to 60	95 to 98	1 month
Tomatoes, ripe	40	95 to 98	10 days

Storing in the Field.—Field storage, in trenches and pits and by mounding on the surface of the ground, is still practiced to some extent. Trenches are used for storing cabbage and celery, and pits for cabbage, turnips, beets, carrots, parsnips, potatoes, and sweet potatoes. All of the crops mentioned, except celery, are sometimes placed in piles on the ground and covered with hay, straw, or other litter and then with soil. The covering of soil should be heavy enough to prevent severe freezing.

Field storage is unsatisfactory and is giving way to other methods. The main disadvantages of this type of storage are: (1) the temperature and moisture cannot be controlled, hence under unfavorable climatic conditions large losses are likely to occur, (2) the produce can be removed only with difficulty when the ground is frozen and this may prevent marketing at the time desired, (3) the product not removed may be injured when the pit or mound is opened during cold or wet weather, and (4) the labor required to store and remove the products from pits or mounds is large.

During the time vegetable products are removed from field storage the weather and the soil conditions are usually unfavorable for such work. This is one of the factors that has caused a change in the method of storage on many farms.

The only advantage in field storage is that it is always available and any amount of space can be used as required. Many growers use field storage because they believe it is cheap, but when labor is taken into consideration it is an expensive method.

For short storage periods the mound above the surface of the ground is fairly satisfactory. A well-drained location should be selected so that no surface water runs about the base of the mound. The surface should be leveled and it is desirable to have two small trenches across the bed, at right angles to each other, to provide for ventilation at the bottom. Boards or troughs are often placed over the trenches and, at the intersection of the trenches, a small open box is set on end to form a flue up through the pile of vegetables. The earth floor is covered with 4 or 5 inches of hay, straw, or other litter and the product is placed on this in a conical pile around the flue. A covering of straw, hay or similar material is put over the pile and over this a layer of soil. The covering of soil should be only a few inches thick at first, but increased as the weather gets colder. The ends of the trenches and flue should be kept open for ventilation until it is necessary to close them to prevent freezing the product. It is better to make several small mounds rather than to make one large one because when a mound is opened it is best to remove the entire contents.

Storing in Cellars.—The ordinary house cellar is used to a considerable extent for the storing of root crops for home use and also for market. If it contains a heater, this is one of the poorest places in which to store vegetables, as it is likely to be so warm and dry that the products will shrivel. However, by partitioning off a room, which can be kept cool and fairly moist, the house cellar is satisfactory. The storage room should have an opening to the outside for ventilation.

Outdoor cellars, made especially for storing root crops, usually give better results than the house cellar. With proper construction the temperature and moisture can be controlled to some extent. This type of storage structure may consist of a pit with a gable roof covered with sods or soil, or a more elaborate structure. Some of the more elaborate are built in a depression or ravine and covered with soil except at the ends. The structure built into a side hill, or in a ravine and covered with soil, is preferable to the pit type since the soil on the sides and top prevents rapid changes in temperature. In any case the entire structure should be well insulated and it is desirable to have the exposed end face the south. Strahan (1917) gives the following rules for the construction of root cellars in New York:

1. A root cellar should be located, when possible, in a sidehill facing the south or the southeast.

2. It should be completely covered with at least 2 feet of earth. When this is impossible by reason of the topography, the roof should be thoroughly insulated, special attention being given to the point where the roof joins the wall.

3. It should be provided with ventilation approximately as follows:

For cellars of from 1,000 to 5,000 cubic feet capacity at the rate of 60 to 80 square inches of flue area per 1,000 cubic feet capacity.

For larger cellars, from 5,000 cubic feet up, at the rate of from 45 to 60 square inches of flue area per 1,000 cubic feet capacity.

Intake ventilators should be provided of approximately the same area as the outtake flues. The inside ends of these should be located near or at the floor. The drain may be utilized as an intake ventilator.

4. Drainage should be provided by ordinary vitrified sewer pipe not smaller than 4 inches in diameter, and if intended for use as a ventilator not less than 6 inches. It must be thoroughly screened at both ends.

5. Doors should in all cases be double. Windows should be constructed in such a way as to make possible thorough insulation in cold weather by banking them with straw or other similar material. They should be well screened.

6. A dirt floor seems to be preferable to a concrete floor where good solid footing can be obtained. A concrete floor is preferable where it is necessary to exclude ground water due to local springs that cannot be diverted through drains.

Storage cellars are best suited to the storage of beets, carrots, parsnips, turnips, and potatoes since these products keep best where the humidity is relatively high.

Storing in Aboveground Houses.—Common storage houses built entirely above the surface are extensively used in storing sweet potatoes, onions, and cabbage, and also to some extent for other products. Where it is necessary to have a dry atmosphere in the storage house the cellar, or structure of the semicellar type is not satisfactory since it is difficult to control the moisture in structures of this kind.

The advantages of this type of storage over any of the others mentioned are: (1) moisture can be controlled more readily, (2) products can be put in and taken out with less work and less discomfort, (3) grading and packing can be done to better advantage than from field storage or even in most types of cellars.

The character of construction of storage houses depends mainly on the type of product and the region in which it is to be stored. The colder the region the greater the insulation needed. Sweet potato storage houses in the South differ considerably from the cabbage and onion houses in the North, yet the same general principles of insulation and ventilation are applied in the two regions.

Cold Storage.—During recent years many vegetables have been stored to some extent in cold-storage warehouses where artificial refrigeration is used. The tendency is toward a greater use of this type of storage. The main advantage of cold storage over common storage is in the control of temperature and humidity, especially the former. In cold-storage warehouses the temperature can be kept at the desired point regardless of the weather condition, provided the building has been constructed and equipped properly. This ready control of temperature is not possible in any other type of storage, consequently less loss is sustained under refrigeration than in common storage. For this reason cold storage is being used even for products which keep fairly well in common storage. At the present time cold storage is used for a large part of the celery that is stored, and to some extent for lettuce, onions, potatoes, carrots, beets, cabbage, cauliflower, and other vegetables.

Location of Storage Houses.—In the early development of storage, the houses usually were built on the farm for use by the owner for his surplus for home use, or for sale. While farm storage is still used to a considerable extent the tendency is toward commercial-storage houses in the cities, or at some central railroad point in the producing region. The change from storage on the farm to use of large, commercial houses makes for more efficient storage. The main advantages of the large commercial houses over the small storage structures on the farms are: (1) lower cost per cubic foot of storage space, (2) lower maintenance and management cost, (3) usually more efficient management, because large-scale storage permits of employment of efficient managers who devote their time to the business, (4) usually better equipment for handling produce at the storage house and therefore less labor required in doing the work, and (5) better location with reference to transportation facilities to markets. Produce stored in farm storage houses must be hauled to the market or to the shipping point during late fall and winter when the roads are likely to be bad and the weather cold. Sometimes it is impossible to get the farm-stored produce to market when there is the greatest demand and very often it is not safe to expose vegetables to the weather during winter. These factors often cause farmers to miss good narkets. When the produce is stored in the consuming centers or on a good transportation line it can be placed on the market at any time, and or this reason central storage houses are more popular than farm storage nouses.

Common storage houses, those having no artificial means of cooling, are usually located on the farms, or at some central point in the producing region. Cold-storage houses are located mainly in the cities although a small percentage are located in small towns or villages in fruit and vegetable regions. The main advantage of locating storage houses in the cities is the convenience of marketing.

Cold-storage space in the cities is usually controlled by dealers, hence the producer gets only an indirect benefit from such houses. This has led growers, in many sections, to build cold-storage plants in the producing region. There is an advantage in having cold-storage houses near the producing region especially for very perishable products such as celery and lettuce. The sooner perishable products are placed in storage after they are harvested the longer they will keep. In fact, if celery and lettuce are placed in storage after being in transit for several days, they will keep only a short time, due to the fact that the temperature in most parts of a refrigerator car is not low enough to prevent deterioration.

Effects of Storage on the Vegetable Industry.—Storage extends the period of consumption of many vegetables and this increases the demand. Without storage the consumer would be able to obtain vegetables only during the time that they are available from the field in various sections of the country. With some crops this would cover a considerable portion of the year while with others it would cover only a short period. Sweet potatoes would be available for only 4 or 5 months and Irish potatoes and onions for 6 or 7 months. Without storage the acreage of many vegetables would have to be reduced, because it would be impossible to consume, during the harvesting period, all that is now grown. Storage therefore increases consumption by lengthening the period of availability of many standard vegetable products.

Storage increases the price the farmer receives for his products, even if they are stored by middlemen, because it helps to prevent market gluts. Cance, Machmer, and Read (1916) found that the average price paid to the farmer for onions for the 3 years 1913–1915 in Massachusetts was $1.14 per 100 pounds and the average wholesale price for onions out of storage was $2.20 per 100 pounds. The difference between $1.14 and $2.20 does not represent profit since it must cover cost of storage, cost of extra handling, loss due to shrinkage and to disease, speculative risk, and profit. The cost of storage itself includes the interest on the investment in buildings and equipment and on the investment in the product itself, fire insurance, and cost of management. Extra handling includes hauling to the storage house, stacking in the room, re-sorting and repacking for market, and the removal from storage to the car or truck for shipping to market. The loss due to shrinkage is much greater than commonly supposed. Gaylord (1927) obtained records from 35 storage houses for onions in 1925–26 and found that the average loss was 11.35 per cent, not including the shrinkage or loss in weight. The shrinkage will average 5 per cent so that a conservative estimate of the total loss would place it at 15 to 16 per cent. Under some conditions the loss is much greater. Similar losses occur in the storage of cabbage. With root crops and potatoes the storage loss generally runs lower than for cabbage and onions, but it is considerable and must be taken into consideration in determining whether to sell in the fall or to store the product.

Often it is stated that the time for the farmer to store onions, potatoes, cabbage, and other crops is when the price is high in the fall and the time for him to sell at harvest, or soon thereafter, is when the price is low in the fall. The farmer is more likely to store when the price is low. While it generally is true that the farmer loses money by storing when the price is low in the fall, it is evident that the price would be still lower if all of the crop were dumped on the market at harvest time. In other words, the advice to the individual farmer not to store when the price of potatoes is low in the fall may be safe, but it would be disastrous if every one followed it. Both the producer and the consumer would suffer.

CHAPTER XVI

PERENNIAL CROPS

Asparagus	Jerusalem Artichoke (Girasole)
Rhubarb	Sea Kale
Artichoke	

Perennial crops occupy the land for a period of years and therefore should be located where they will not interfere with the usual tillage operations. It is advisable to grow these crops in an area to themselves. In the home garden they should be planted on one side, or at one end, so that the remainder of the garden can be treated as a unit in plowing and harrowing. For the same reason on commercial vegetable farms the perennial crops should be grouped together in one field, or in one portion of a field. After perennial crops have been planted manures and fertilizers are applied to the surface. Except for the points mentioned the perennial crops have little in common as far as cultural practices are concerned.

ASPARAGUS

Asparagus is one of the most delicate, wholesome, and appetizing products of the garden. Its early appearance in the spring, together with the fact that an asparagus bed when once established will produce for many years, makes it of special importance in the home garden as well as in the market garden and on the truck farm. As a canned product asparagus is one of the best because it retains its flavor better than most other vegetables.

Statistics of Production.—The production of asparagus for market and for canning is an important industry. The acreage grown for market and for canning increased from an average of 30,420 acres per year for the years 1918–1922 to 110,960 acres for the period 1933–1937. The average acreage, production, and farm value of asparagus grown in the United States for the 5-year periods 1918–1922, 1923–1927, 1928–1932 and 1933–1937 are shown in Table XVIII. The 1937 acreage of asparagus grown for consumption in the fresh condition in 14 leading producing states was 64,320, over four times the average acreage for the period 1918–1922. The leading states in the production of asparagus for market in 1937 were California with 23,510 acres, New Jersey with 11,000 acres, South Carolina with 8,000 acres, Illinois with 3,600 acres, Washington with 3,600 acres, Georgia with 2,700 acres, and Maryland with 2,400 acres. Nearly all of the asparagus grown for canning was produced in California.

The estimates given in Table XVIII probably are low as they do not include production in many states such as New York, Connecticut, Rhode Island, Indiana, and other northern states where the crop is grown for local markets.

TABLE XVIII.—ESTIMATED ACREAGE, PRODUCTION, AND VALUE OF ASPARAGUS GROWN FOR MARKET AND FOR CANNING IN THE IMPORTANT PRODUCING STATES BY 5-YEAR PERIODS, 1918–1937
(U. S. Bur. Agr. Econ., *Crops and Markets*)

Years	Acres	Production	Value (000 omitted)
		For Market	
1918–1922	15,508	1,512,000 crates	$ 4,573
1923–1927	31,402	2,781,000 crates	8,722
1928–1932	59,960	4,739,000 crates	9,615
1933–1937	65,790	5,612,000 crates	7,859
		For Canning and Manufacture	
1918–1922	14,912	21,980 tons	$ 1,845
1923–1927	35,760	47,100 tons	3,845
1928–1932	39,120	54,250 tons	4,120
1933–1937	45,170	54,248 tons	3,896
		Total Market and Canning	
1918–1922	30,420	....	$ 6,418
1923–1927	67,162	....	12,567
1928–1932	99,080	....	13,735
1933–1937	110,960	....	11,755

History and Taxonomy.—Asparagus is indigenous to Europe and Asia where it has been in cultivation for over 2,000 years. It was prized as a food by the Greeks and Romans and valued for the medicinal properties of all its parts. Asparagus has been grown in the gardens of America ever since the earliest settlements were established.

Asparagus, a genus of the lily family, has at least 150 species native of Europe, Asia, and Africa. Some of these are herbaceous and some woody, and both erect and climbing forms are common. In addition to the edible asparagus, the genus contains the so-called "smilax" used by florists and the ornamental plants known as "asparagus ferns."

The species of this genus are devoid of ordinary green leaves, the green branches functioning as leaves. The small scales or spines on the stems are the true leaves.

The garden asparagus, *A. officinalis* Linn. var. *Altilis* Linn. is a perennial, dioecious herb 4 to 10 feet tall. The male flowers are yellowish green and conspicuous, while the female flowers (on separate plants) are less conspicuous. The fruit is a three-celled berry which becomes red as it matures. The seeds are large (⅛ inch or less in diameter), rounded at the back but more or less flattened on one side, black in color.

Soil Preference.—Asparagus can be grown on nearly all kinds of soils, but a deep, loose soil is preferred. Sandy and sandy-loam soils are used to a large extent in many asparagus growing sections, although some of the muck lands of California are considered almost ideal. For market asparagus, where earliness is of great importance, sandy and sandy-loam soils have a decided advantage. The soil should be well drained since the plant will not endure being submerged for any great length of time.

The soil for asparagus should be thoroughly prepared since the crop occupies the land for many years and there is no opportunity for further preparation after the roots are planted. It is desirable to have the land thoroughly freed of noxious weeds as it is difficult and expensive to control weeds in an established bed. The land should be well plowed to the depth normally practiced on the particular tract to be used. On ordinary upland soils a depth of 8 inches is sufficient. The old practice of deep plowing and then trenching or subsoiling is no longer advocated since it has been found that deep planting of the roots is not desirable. After being plowed, the soil should be prepared thoroughly by harrowing, and dragging if necessary to get a good loose surface.

Manures and Fertilizers.—The experimental data on fertilizing asparagus are conflicting and generally inconclusive. Results of experiments by Brooks and Morse (1919) in Massachusetts seem to show that on a sandy-loam soil chemical fertilizers produce as large yields as manure and chemical fertilizers. In this experiment, 466 pounds of nitrate of soda, 300 pounds of 14 per cent superphosphate, and 346 pounds of muriate of potash produced as large yields as 10 tons of manure plus 466 pounds of nitrate of soda, 300 pounds of 14 per cent superphosphate, and 260 pounds of muriate of potash per acre. The results cover a period of only 4 years. Wessels and Thompson (1937) reported results of experiments on a sassafras, silt-loam soil in which manure at the rates of 10 and 20 tons, plus a liberal application of phosphorus, did not produce such large yields as a moderate application of a complete fertilizer during the first 4 years. In the next 5 years, however, 20 tons of manure plus phosphorus produced a significantly higher yield than the complete fertilizer. In spite of the large yields on the heavily manured plots, the use of manure was not profitable. From the results of these and other experiments, it appears that one could not afford to pay very much for manure (probably not over $2.00 per ton) for use on the asparagus bed.

Since asparagus is grown on such a wide range of soils, it is not possible to give specific fertilizer recommendations that would be generally applicable. Jones and Robbins (1928) stated that on the rich soils of the Delta in California very little increased production has been obtained from the fertilizers that have been tried. In most other asparagus-growing sections of the United States, liberal fertilization is practiced and experimental evidence justifies the practice. On unmanured sandy and sandy-loam soils, 100 pounds each of nitrogen and phosphoric acid (P_2O_5) and 150 to 200 pounds of potash should give good results. Results reported by Wessels and Thompson indicate that on a sassafras, silt-loam soil on Long Island 100 pounds of nitrogen, 125 pounds of P_2O_5, and 160 pounds of potash (K_2O) would give good results. When manure is used in considerable quantities, it is desirable to supplement it with phosphorus and readily available nitrogen.

In most experiments, muriate of potash has given better results than sulphate of potash.

There is considerable difference of opinion as to the best time for the application of fertilizer to the asparagus bed. Results of experiments in Massachusetts and in Maryland indicate that spring applications are better than those made at the end of the cutting season. Under most conditions spring application seems to be preferable to later ones, especially for the potash and phosphoric acid. It might be better to apply part of the nitrogen in the spring and part at the end of the cutting season, but the later application should be of some soluble salt of nitrogen. One serious objection to applying all of the fertilizer after the harvest season is over is that a long period of dry weather may occur and the fertilizer not become available until too late in the season to be of any value.

Soil Reaction.—Asparagus does not grow well on a highly acid soil; when such soils are used, liming is desirable. On mineral soils, it is desirable to maintain the reaction between pH 6.0 and 6.7. On natural limestone soils asparagus is grown satisfactorily on soils that are neutral or slightly alkaline, but it is not desirable to bring an acid soil to neutrality because of the expense involved and also because the lime might render unavailable some essential element. When asparagus is grown on a soil that has a favorable reaction it is desirable to use fertilizers that are neutral in reaction.

Use of Salt.—Years ago salt was considered essential to success in growing asparagus, but at the present time it is not used by many commercial growers. It is certainly not essential as good asparagus is grown without the use of salt. Experimental results have been conflicting and inconclusive. Walker (1905) conducted experiments in Arkansas on the use of salt and reported increased yield on the salted plot. The results were obtained for one season only and the treatment was not replicated, therefore, little dependence should be placed on them. Salt applied at the rate of 1,000 pounds to the acre had no applicable effect on weeds, but heavier applications (2 pounds per square yard) did keep them down. At the Maryland Station 2,000 pounds of salt had no noticeable effect on weed growth. Rudolfs (1921) conducted experiments in which salt was used as a top dressing. He used common rock salt and applied it at the rate of 150, 300, and 500 pounds to the acre on 2-year old and 11-year old plants. This experiment was carried on for 2 years and the salt seemed to increase the number and weight of spears, but those on the salted areas were of lower grade than those on the check plots. The number of stalks and the total length of the plants increased in regular order on the salted areas. The asparagus seemed to be stimulated directly by the salt since the weeds were kept down by hand on all plots. More recent experiments at the Rhode Island Station reported by Hartwell, Smith, and Damon (1928) show that sodium chloride and sodium carbonate were beneficial when used with an insufficient quantity of potash. The chloride was superior to the carbonate, and the opinion is expressed by the authors that the chlorine rather than the carbonate radical has been useful in some way as a supplement to the potassium. The carbonate is less acidic than the chloride, but attempt was made to maintain approximately the same reaction under these two treatments. It was observed that more plants died in the plots treated with sodium carbonate than in those having the sodium chloride treatment. When 1,200 and 1,500 pounds of soda per acre were applied over weeds the carbonate killed chickweed, but had little effect on purslane, while the chloride had little effect on either.

Working (1924), using solution cultures, found that asparagus seedlings grew better where sodium was used, except at the concentration of 0.5 M, than in solutions without sodium. Chlorine did not show the specific action that might have been expected from fertilizer experiments reported by others.

The evidence on the effect of salt on the growth of asparagus does not justify definite recommendation either for or against its use. It seems safe to say that salt, in applications up to 1,500 to 2,000 pounds to the acre, is of little or no help in controlling weeds. While applications of salt may have other beneficial effects under some conditions, it is doubtful if its use is justified when the asparagus is well fertilized with nitrate of soda and muriate of potash (KCl), or kainite. Both sodium and chlorine, as well as nitrate and potassium, would be supplied in such a fertilizer, so that applications of salt would add only additional quantities of sodium and chlorine. Kainite contains sodium chloride and other salts as impurities. In case highly concentrated fertilizers, containing no sodium, were used addition of salt might be worth while. More experimental evidence is needed on this problem.

Growing Asparagus Crowns.—Asparagus crowns are grown from seed planted in a well-prepared seedbed where the plants are allowed to grow for one full growing season before being planted in the permanent bed. The asparagus grower may grow the crowns or may buy them from some plant grower. Where the crop is to be grown on a large scale it usually is cheaper to grow them than to buy them; there are some other advantages in growing them at home. If the grower produces his own seed, as well as the crowns, he has knowledge of the source and of the productiveness of the parent plants; he has opportunity for rigorous selection of the crowns; he has the crowns available when wanted for planting and can plant them soon after digging—a decided advantage.

While many growers of asparagus crowns take special care in selecting the seed, in growing the crowns, and in selecting only the well-developed vigorous ones, some growers pay little attention to the source of the seed or to the grading of the crowns. Crowns should be purchased only from sources known to be reliable.

Under average field conditions asparagus seed is slow to germinate, the time required varying from 2 to 6 weeks, depending on the temperature and moisture of the soil and the depth of planting. Some authorities have believed that the seed had a period of dormancy, but Borthwick (1925) has shown that this is not true. He found that the seed will germinate immediately after maturing if the environmental conditions are satisfactory. Germination is very slow at relatively low temperature (below 20°C.). The rate of germination at different temperatures under laboratory conditions is given in Table XIX.

The optimum temperature seems to be about 30°C. (86°F.), although at 25° the rate was not much below that at 30°. At 40° there was no germination in 17 days. The slow germination at low temperatures probably is due to low rate of water absorption. Experimental results obtained by Borthwick showed that water absorption increases with a rise in temperature between 10° and 40°C. Soaking hastens germination, even when the seed is planted subsequently in cold soil. Seeds soaked at 25° to 35°C. germinated more quickly than those soaked at higher or at lower temperatures. Soaking for 3 to 5 days at 30° to 35°C. is recommended. After the seed has been soaked it should be spread out to dry. During the drying, the seed should be stirred to hasten evaporation on the surface and to have it dry uniformly. The drying should not be continued longer than necessary to allow the moisture on the seed coat to be evaporated, for if the seed becomes too dry it loses vitality.

TABLE XIX.—EFFECT OF TEMPERATURE ON RATE OF GERMINATION OF ASPARAGUS SEED
(*Calif. Agr. Exp. Sta. Tech. Paper* 18)

Temperature of germinating chamber, ° C.	Percentage germination in given number of days							
	3	4	5	6	8	10	12	17
10	0	0	0	0	0	0	0	0
20	0	0	2	4	11	14	..	27
25	0	25	65	84	98	98	98	98
30	0	50	74	83	91	95	96	97
35	0	5	..	16	31	55	67	
40	0	0	0	0	0	0	0	0

The land to be used for the seedbed should be well prepared and well supplied with nutrients. Unless the soil is already rich it should be liberally fertilized with a complete fertilizer approximating a 1:1:1 ratio. It is desirable to plant the seed as early as the weather and soil conditions will permit. Planting may be done by hand or with a drill, the former method being practicable only on small areas. Planting usually is done with a seed drill, preferably one that drops one seed in a place and spaces evenly, since thinning is difficult. The rows may be 18 to 24 inches apart for hand cultivation and 30 to 36 inches apart for horse cultivation. The plants should be spaced 3 or 4 inches apart in the row, and since it is difficult to remove surplus plants, it is desirable to space the seed this distance apart.

Clean, shallow cultivation should be given mainly to control weeds. Deep cultivation is not desirable as this destroys some of the roots and thus checks growth.

Under ordinary conditions, well-grown, 1-year-old roots are best. Older roots are difficult to dig, and are injured in digging if they have made good growth. Old stunted roots are inferior to younger unstunted ones.

Male versus Female Plants.—Asparagus is "dioecious," that is, it has pistillate and staminate flowers on different plants. Occasionally perfect flowers occur, but this is rare. Field-run plants will average about 50 per cent males and 50 per cent females. Tiedjens (1924) reported experimental results with the Washington strain in which the male plants produced about 25 per cent greater yield than the female plants, but the latter produced larger spears. Results of studies on the Palmetto variety made by Robbins and Jones (1928) in California are similar to those reported by Tiedjens. The data on number of spears per plant, the average weight per spear, and the yield per acre for staminate and pistillate plants are given in Table XX.

TABLE XX.—COMPARISON OF THE SIZE AND NUMBER OF SPEARS AND YIELD PER ACRE FROM STAMINATE AND PISTILLATE PLANTS

(Robbins and Jones)

Year	Average number spears per plant		Average weight per spear in grams		Yield per acre in pounds	
	Staminate	Pistillate	Staminate	Pistillate	Staminate	Pistillate
1925	3.0	2.0	18.1	19.9	372	278
1926	16.6	9.4	22.8	26.5	2,407	1,576
1927	24.5	14.9	25.5	31.3	3,989	2,949
1928	26.4	18.5	25.6	33.0	4,819	3,864

The staminate plants produced a larger number of spears per plant and a higher yield per acre, but the average size of spears was smaller. For the 2 years, 1927 and 1928, spears from some of the rows were graded into five grades, below ⅜ inch, ⅜ to ½, ½ to ⅝, ⅝ to ¾, and over ¾ inch. The data from 1928 are given in Table XXI.

TABLE XXI.—TOTAL YIELD OF ASPARAGUS IN EACH GRADE OF STAMINATE AND PISTILLATE ASPARAGUS PLANTS

(Robbins and Jones)

Sex	Yield in pounds per acre					
	Below ⅜ inch	⅜ to ½ inch	½ to ⅝ inch	⅝ to ¾ inch	Over ¾ inch	Total
Staminate	625.9	2,226.5	1,441.5	424.7	15.1	4,733.6
Pistillate	156.6	1,135.9	1,513.3	851.5	127.7	3,793.9

In only the two smallest grades did the staminate plants produce a larger yield than the pistillate plants. From the standpoint of profit the larger total yield from the staminate plants might be offset by the larger yields of the better grades from the pistillate plants. However, the staminate plants produced about 470 pounds more spears above ⅜ of an inch than did the pistillate plants.

In the eastern part of the United States asparagus plants do not blossom the first year; therefore, it would be impossible to select the crowns on the basis of sex without growing them for 2 years. The superiority of 1-year-old crowns has been demonstrated so that it is doubtful if it would be profitable for asparagus growers in the East to make any attempt to select only staminate plants. Growing plants in the nursery for 2 years would involve much extra labor, the use of land 2 years instead of 1, and the discarding of about half of the plants. These would add greatly to the expense of plants and it is doubtful if the yield from 2-year-old staminate plants, as compared to 1-year-old field-run plants, would justify the extra expense. In California, where the plants blossom the first year, selecting and planting staminate plants and discarding the pistillate ones might be profitable. More evidence is needed to settle this question, even for California conditions.

Digging the Crowns.—The crowns may be dug in the fall after growth has ceased and stored in a good storage, or left in the ground until time for planting. Where they are grown for sale they usually are dug and stored so as to be available for shipment at any time. When left in the ground over winter it is desirable to cover them lightly with straw or other material to protect against alternate freezing and thawing which may result in heaving the crowns.

The crowns may be plowed out with a two-horse moldboard plow which turns them upside down. They are lifted out of the loose soil with a short-handled fork. Another implement, similar to the bean harvester, is used for digging. The digging part consists of a U-shaped knife that runs under the mass of fleshy roots. The knife should be at least 8 inches wide at the bottom with an upward tilt toward the rear so as to lift the crowns and make it easy to take them out with a fork. Care should be taken in digging to injure them as little as possible. If the digging is to be done in the fall the tops should be cut off and removed, or burned so as not to interfere with the operation.

The best storage temperature for asparagus crowns is about 40°F., but they can be kept for a considerable period at higher temperature if the atmosphere is fairly dry. On the other hand, the crowns should not be allowed to dry out, since growth is slow after they have become desiccated. It is best to plant the crowns as soon as feasible after they are dug.

Planting Asparagus Crowns.—As has been suggested, 1-year-old crowns are recommended, since experience seems to indicate they give better results than older ones. If the crowns are left for 2 years they become checked in growth by crowding and also the roots become so intertwined that they can be separated only with difficulty and with considerable injury. One-year-old crowns can be dug with less injury to the roots and consequently with less interruption to growth.

Only well-grown crowns of good size, containing large buds, should be planted since many of the small weak ones do not survive. This results in a poor stand of plants and low yields. Results of experiments carried on in Pennsylvania and reported by Myers (1915) show that the yield from the small crowns was much below that for the larger sizes. The average annual value of the first six crops was $539.00, $520.00, and $418.00 per acre from grade 1, grade 2, and grade 3 respectively. Obviously, it would have paid better to have discarded the grade 3 crowns since the gross return was over $700 less per acre for the 6 years from grade 3 plants than from grade 1. Two sizes are shown in Fig. 15.

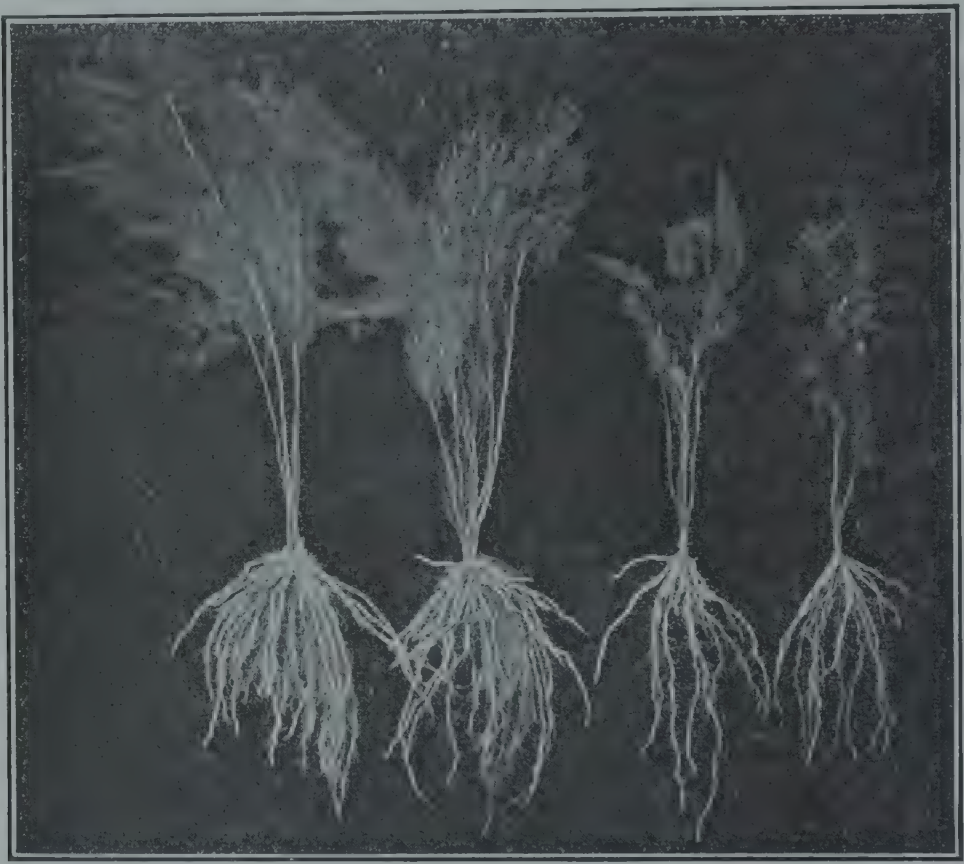

FIG. 15.—Two sizes of one-year-old asparagus plants; the two on the left are satisfactory the two on the right are rather small. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

In most sections of the United States the crowns are planted in the spring as early as the soil can be put in good condition. It is desirable to do this before growth begins. Fall planting is practiced to some extent in the South.

The depth of planting varies from 6 to 14 inches depending on the soil type. On the light peat soils of the Delta region of California, according to Hanna (1935), the depth of planting varies from 8 to 14 inches, 10 inches being the most common depth. Relatively little experimental work on depth of planting has been done, but Hanna reports that 10 years' data on a silt-loam soil at Davis, California, show an annual decrease of 1,041 pounds to the acre when crowns were planted 12 inches deep as compared with a depth of 8 inches. Another experiment on peat soil for three years showed no difference in production between 8 and 12-inch depths, but a reduction in yield when the crowns were planted 4 inches deep. On upland soils it is probable that 8 inches should be the maximum depth of planting and on heavy soils the covering should not be over 6 inches deep. Regardless of the depth of the furrow, the crowns should not be covered over 2 or 3 inches deep at planting time.

The furrow in which the crowns are set is made with a turn plow running twice in the row and throwing the furrows in opposite directions, or with a double moldboard plow. The distance between the rows varies considerably. In growing green asparagus, in most sections of the East, the rows are spaced 4 to 5 feet apart, although some growers prefer 6 feet. When the asparagus is to be blanched the rows are spaced 6 to 8 feet apart, the wide spacing being desirable for the purpose of ridging the soil over the rows. The usual spacing between the plants in the rows is from 18 to 24 inches, although some growers give less space and others more. Jones reported results of spacing experiments covering a period of 7 years in which plants were spaced 12, 18, 30, and 36 inches apart in rows 7.5 feet apart. There was no significant difference in total yields between 12- and 18-inch spacing; but above 18 inches the yield decreased considerably. In size of spear, the 18-inch spacing was superior to the 12-inch and about equal to the wider spacings. Haber (1935) reported results of experiments in which plants were spaced 1, 2 and 3 feet apart in the row with rows 3, 4, and 5 feet apart. His results indicate that rows 3 feet apart are too close and that spacing one foot apart in the row results in a decrease in size of spear as compared with wider spacing. Plants spaced 3 feet apart showed no significant superiority over those 2 feet apart. In experiments at Ithaca, N. Y., covering 6 years, the total yields of marketable asparagus decreased as the spacing in the row increased from 12 to 18 to 24 inches and as the distance between rows increased from 4 to 5 feet. The difference in yield between 12- and 18-inch spacing in the row was not great, but there was a significant decrease in yield from the 24-inch spacing and no appreciable difference in size of spear between the 18-inch and 24-inch spacings.

Since asparagus crowns increase in size throughout the commercial life of a planting, it does not appear desirable to set the plants closer than 18 inches apart in the row; this distance might be increased to 2 feet under some conditions. The distance between rows should not be less than 4 feet for unblanched asparagus and not less than 6 feet where the spears are to be blanched. The spacings should be increased when the crop is grown on good silt-loam or muck (peat) soils. Hanna states that the rows should not be less than 7 feet apart for blanched asparagus in California.

After the furrows are made the crowns are dropped by hand, care being taken to see that the buds are up. In small plantings the large roots are spread out by hand, but where large acreages are set this is seldom done. As soon as feasible after the crowns are placed in the furrow, they are covered to the depth of 2 or 3 inches with loose soil. When the crowns send up shoots through the soil covering more soil is added and this is repeated at intervals, so that before the end of the season the furrow is filled. The filling of the furrow is done as the land is cultivated. The crowns should never be covered to the full depth of the furrow at first as many of the buds would be smothered before reaching the surface.

Intercropping.—In many sections no spears are harvested from a new planting until the beginning of the third year, or after the plants have had two seasons' growth. This has led to intercropping in order to get some money return from the land every year. Where the rows are far enough apart to allow ample space for the intercrop and the asparagus, intercropping is a satisfactory practice during the first 2 years, provided sufficient nutrients are available for both crops and a suitable crop is grown. Snap beans, early cabbage, lettuce, or any other small-growing crop may be planted between the rows of asparagus. Tall-growing or long-season crops should not be grown with asparagus on account of shading and competition for moisture and nutrients. The cultivation required for a good growth of asparagus will be sufficient for the companion crop and the return from the latter should go a long way toward paying for the cost of growing both.

Cultivation and Care.—Cultivation and hand-hoeing should be given as often as necessary to keep down weeds. During the cutting season it is difficult to keep the weeds under complete control in the rows without breaking or otherwise injuring the spears. For this reason, weeds usually have a good start by the end of harvest. These weeds can be destroyed by running over the rows with a cultivator with knife attachments that run just beneath the surface, cutting off all weeds. Of course, this will cut off all the spears as well as the weeds, but if this is done on the last day of harvesting little injury will be done. This will give the asparagus a chance to get ahead of the weeds and will reduce the labor of cleaning the beds. After the tops start growth, weeds in the row can be controlled by covering them with soil during cultivation or by hand hoeing and weeding.

Cyanamide, a nitrogenous fertilizing material, has been used with good results in controlling weeds in asparagus fields in many regions. In early experiments, pulverized cyanamide was applied as a dust on the weeds when the foliage was wet. This method of application, at the rate of 75 to 100 pounds to the acre, was found to be satisfactory when made while the weeds were very small and when a good duster was used. The more common practice now is to apply either the powdered or granular form to the soil in a strip 12 to 18 inches wide over the row, using 250 to 500 pounds to the acre. In some cases one application, made before or at the beginning of cutting, has given control, but in other cases an additional application at the end of harvest has been found desirable. On sandy and sandy-loam soils, not over 300 pounds of cyanamide should be used to the acre at one time. When cyanamide is used for weed control, the nitrogen used as fertilizer may be reduced or eliminated since cyanamide contains about 21 per cent of nitrogen.

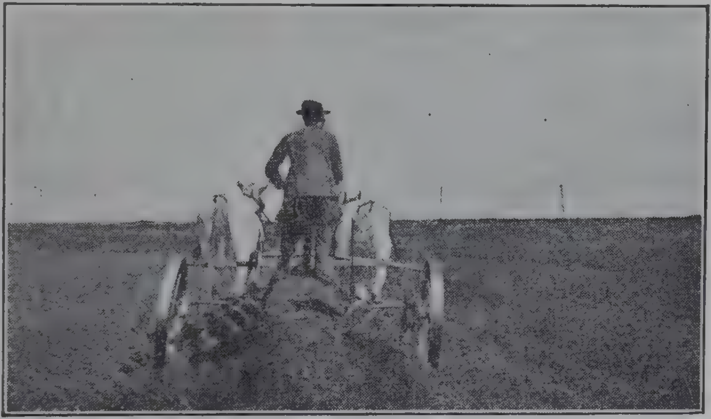

FIG. 16.—A disk asparagus hiller used for making ridge over the row in the production of white shoots. (*Courtesy of U. S. Dept. Agr.*)

After the first season, the bed should be disked and harrowed thoroughly each spring before growth begins. If the tops have been left standing over winter they can be broken over by a drag on a dry spring day. After the tops are broken over, they should be disked into the soil. This may require disking lengthwise and across the rows. If the fertilizer is applied in the spring it should be done before the land is harrowed as the harrowing mixes it with the soil and gets it well distributed. Cultivation and hoeing are necessary to keep down weeds after the bed is established as well as during the first season. In all tillage operations care should be exercised to prevent injury to the crowns of the plants.

Where blanched asparagus is desired it is necessary to mound the soil over the rows in order to bleach the young spears. On large plantations this is done by means of a plow, a disk harrow, or with an asparagus hiller similar to that shown in Fig. 16. The hilling is started in spring just before growth begins and continues through the cutting season as needed to keep up the mounds. After the cutting season is over, the mounds are leveled by means of a plow, disk, or other implement and flat culture is given for the remainder of the season. If any of the fertilizer is applied at the end of the cutting season it should be applied between the rows and mixed with the soil by cultivating. It should be borne in mind that the treatment given the asparagus bed during the growing season determines, to a very large extent, the quality and quantity of the crop the following year. The plant food used in the production of shoots in the spring and early summer is manufactured in the foliage and stored in the roots during the previous season's growth. For this reason a strong, healthy growth of foliage is essential to a good yield of shoots.

Green versus Blanched (White) Asparagus.—During recent years a marked preference has been shown for green asparagus, due perhaps to the increasing knowledge of the value of green vegetables in the diet. On some, if not most, eastern markets green asparagus brings a higher price than the same grade of the blanched product. Waugh and Kroeck (quoted by Tiedjens) obtained data to show the relation between the price paid for asparagus on the Boston market and the length of the green portion of the spear. With spears 9 inches long the price increased on an average of 38½ cents per dozen bunches for every additional inch of green. For example, when there was only 3 inches of green the price was $1.39 per dozen bunches; 4 inches of green $1.78; 5 inches $2.16; 6 inches $2.54; 7 inches $2.93; 8 inches $3.31; and 9 inches, or the entire length of the spears, the price was $3.70 per dozen bunches.

In California the asparagus grown for canning is blanched, but that shipped to market is green. The practice has changed in California in recent years due to the increasing preference and demand for the green product. Most other sections of the United States grow green spears.

Removing the Tops.—Formerly some authorities advised cutting and burning the asparagus tops as soon as the berries turn red. It was argued that if the berries are allowed to ripen they fall off and the seeds germinate and the seedlings become troublesome. It was suggested also that burning destroyed the rust on the old plants. It is now known that if the tops are removed while they are still green the roots are deprived of a large quantity of manufactured food. For this reason it is desirable to let the tops stand until they are dead. The tops are a great protection to the roots in regions where low temperatures occur, since they hold the snows and thus often prevent deep freezing and rapid changes in soil temperature. Under such conditions, it is best to let the tops stand until spring and then to disk them into the soil. Burning the tops is wasteful since an acre of asparagus is equivalent in humus-forming material to several tons of average stable manure.

Morse (1916) has shown that early removal of asparagus tops decreases the quantity of reserve food material stored in the roots and also that most of the material used in growth of shoots is stored in the roots during the previous season. Samples of tops were taken for analysis in August, after blossoming but before berries were formed, and in October, when the stalks had turned yellow. To determine how fast translocation took place the branches were removed and analyzed by themselves. Table XXII gives the results of the analysis reported by Morse.

Table XXII.—Analysis of Asparagus Tops
(*Mass. Bull.* 171)

	Summer tops		Fall tops	
	Stems	Branches	Stems	Branches
Dry matter	23.76	28.43	24.18	32.15
Ash in dry matter	7.39	7.31	9.36	8.51
Protein	7.94	17.31	4.47	11.00
Fiber	44.83	29.76	45.11	32.02
Fat	1.38	4.89	1.35	5.23
Nitrogen-free extract	38.46	40.73	39.71	43.24
Total sugar	14.28	8.68	9.34	7.09
Pentosans	15.90	14.15	15.86	14.41
Lignin	8.28	17.90	14.51	21.74
Reducing sugar	12.50	2.99	8.76	3.99
Protein nitrogen	1.03	2.42	0.74	1.56
Amino nitrogen	0.24	0.35	.....	0.20

A study of Table XXII shows that both the sugar and protein disappear with ripening, and appear to be the only groups of constituents subject to translocation. The translocation of sugars as they are formed is indicated by the higher percentages in the stalks than in the branches, both in midsummer and in autumn. Analyses of the roots show that most of the reserve food stored in them in the fall is sugars. Morse suggests that neither sugar nor protein is completely transferred to the roots, because until killed by frost the living cells must still contain active protoplasm and its supply of food.

Duration of a Plantation.—The length of time an asparagus bed will produce profitable yields depends on the treatment it receives. A well-established bed, which receives good cultivation to keep down weeds and good fertilizing each year, should produce profitable crops for 15 to 20 years. In practice, however, usually it is found desirable to renew the planting about every 10 to 15 years. When an old bed produces nothing but small, spindling shoots it should be plowed up. Of course, in order to have a supply of asparagus every year, a new bed should have been started in another location some years before the old bed is destroyed.

Varieties.—True varieties of asparagus are few and the characteristics of these are not clearly marked since there is a constant mixing of blood lines due to crossing in the field. At the present time the Mary Washington, a rust-resistant variety, is being planted more than any other. The Martha Washington is planted to some extent in New England and, while it is more resistant to the asparagus rust than any other variety, it is not so good in other respects as the Mary Washington. The Mary Washington produces large spears that do not branch so quickly as do those of most other varieties and the tips remain closed longer than on any other variety or strain.

The Washington varieties were developed by Norton (1913) at a time when the asparagus rust was so serious as to threaten the entire asparagus industry in this country. They were developed from a cross between a male plant of unknown American origin, grown from seed at Concord, Mass., and a female plant of Reading Giant obtained from England. The male plant was remarkable in transmitting vigor and rust resistance. From this pair was produced the Martha Washington. The male plant was named Washington and a cross between this and a giant female, taken as a seedling from a bed of Reading Giant at Concord, Mass., resulted in the Mary Washington.

Of the older varieties of asparagus Palmetto, Reading Giant, and Argenteuil are somewhat rust resistant. The Palmetto is still grown to some extent and is the most important of the older varieties.

Asparagus Rust.—The asparagus rust (*Puccinia asparagi*) is the only serious disease of asparagus in the United States. It appears on the plant as small reddish-yellow spots on the main stem and on the branches. As the disease develops, the spots enlarge into patches until the whole plant has a reddish brown or orange color, which becomes darker later in the season.

The damage caused by this rust is not seen directly in the marketed product, but reduces the yield by weakening the plants during the summer after the cutting season is over and often killing them. No practicable control measure has been developed for this disease except the use of rust-resistant varieties. Spraying with Bordeaux mixture has been thoroughly tested by several experiment stations but growers have not taken up the practice. The use of rust-resistant varieties is the only solution of this problem.

Asparagus Beetles.—Asparagus is attacked by two species of beetles, the common asparagus beetle (*Crioceris asparagi L.*) and the 12-spotted asparagus beetle (*Crioceris duodecimpunctata L.*). The adult of the common asparagus beetle is slender, blue-black with red thorax and lemon-yellow and dark-blue wing covers. The length of the body is about ¼ inch. The full-grown larva is dark gray, with shiny black head and legs. The 12-spotted asparagus beetle can be distinguished from the common species by its broader back and orange-red color. Each wing cover is marked with six black dots. The larva of this species is orange in color and about ³⁄₁₀ inch long.

Injury by the common asparagus beetle is due to the work of both the adults and larvae to the tender shoots, and to the plants later in the season. The larvae feed on the tender portion of the tops, but the beetles gnaw the epidermis or rind of the stems as well as the tender portions. This injury to the asparagus tops results in weakening the roots. The chief damage inflicted by the 12-spotted asparagus beetle is by the adult on the young shoots in the spring. Later both the adults and larvae feed on the berries.

Injury to the asparagus shoots may be reduced or prevented by cutting all shoots every three or five days. This will remove all eggs deposited on them. When infestation is heavy, it may pay to leave a row here and there uncut to serve as a trap on which the beetles may feed and lay their eggs. They may be poisoned on these plants by dusting with calcium arsenate dust. After the cutting season, the plants can be protected by applications of calcium arsenate dust, 15 pounds mixed with 85 pounds of hydrated lime.

Harvesting.—In most asparagus-growing sections of the Eastern and Middle Western states, the first cutting is made at the beginning of the third season, or after the plants have had two full growing seasons in the permanent bed. In some regions having a longer season, as in South Carolina and in California, asparagus is harvested during the second season or after one season's growth in the field. During the first cutting season the harvesting period is short, usually from 2 to 4 or 6 weeks. After the first cutting season the period of harvest runs from 8 to 12 or 14 weeks. In regions having a relatively short season, 8 weeks' cutting is long enough, for the plants must be allowed to make good growth before frost in order to produce a satisfactory yield the following season.

Asparagus is usually harvested every day during the main portion of the cutting season but, if the weather is cold, every other day or even every third day may be often enough. On the other hand, in very hot weather when the growth is rapid, it is necessary to go over the bed twice a day, especially where blanched shoots are desired. The cutting is done with a knife made especially for this purpose. In cutting one takes hold of the shoot with one hand and with the other inserts the knife to the desired depth (an inch or two below the surface of the soil for green asparagus) and severs the shoot with a downward stroke. Care should be exercised to avoid injuring the crown and the other shoots; hence the knife should be inserted almost straight down beside the shoot, and then tilted slightly to cut off the stalk. One thrust with the knife should be sufficient.

If white asparagus is desired, it is necessary to cut the shoots soon after they force their way through the surface of the soil. They turn green on exposure to the light. White shoots are cut several inches below the surface of the mound of soil, but they should be severed an inch or two above the crowns to avoid injury to the crown.

Since asparagus loses its quality quickly after it is harvested, it should be prepared and put on the market as soon as possible. For the very highest quality, asparagus should be cooked within a few hours after being cut, but this is impossible except where it is produced at home. However, the local gardener has a decided advantage over the grower who lives a long distance from his market.

Washing Asparagus for Market.—The asparagus shoots are taken to the packing shed where they are washed, bunched, and packed. This preparation may be done in almost any kind of building. The necessary equipment and supplies consist of stationary benches or tables, tubs or tanks, brushes, and wire bottom trays for washing, machines for bunching, knives, tape or raffia, shallow pans, crates or boxes, labels, nails, and a supply of water. The shoots are usually washed before bunching; this can be done easily by dousing the tray of shoots a few times. Green asparagus does not always need washing, but the butt ends usually require some rinsing to give the bunch a clean appearance. This is sometimes done after the shoots have been bunched. Some growers prefer to scrub the outside of the bunch of shoots after they have been bunched and tied, and for this a stiff brush is used.

Grading.—Asparagus is taken from the field to the packing shed where it is separated into grades, based mainly on size. The number of grades varies considerably. In some sections no grading is done except to throw out unmarketable spears, in others the marketable spears are separated into two grades; while in still others, as in California, as many as five grades are used. Where two grades are used it is desirable to follow the specifications of the U. S. Bureau of Agricultural Economics.

If the spears are separated into more than two grades those that meet the requirements of U. S. Grade No. 1 should be separated mainly on the basis of size. For most markets three grades are sufficient, the best grade being a fancy product, the second including spears which meet the requirements of U. S. No. 1, and the third corresponding to U. S. No. 2.

Bunching.—After being separated into the different grades the shoots are placed in a bunching machine with the heads all one way, only one grade being put into a bunch. When the bunching apparatus is full, the clamps are closed and the asparagus is tied near each end with tape or raffia. The butts are cut off evenly with a sharp knife and the bunches packed immediately, or else placed in a cool place not exposed to currents of air. The size of bunches ranges from 1 to 3 pounds depending on the market. For local retail trade, small bunches are preferred.

After this the bunches are stood in shallow pans in an inch or two of cold water, where they remain until packed.

Asparagus is sometimes packed in boxes or crates without bunching. When the loose pack is used, the butts are cut off and the spears are laid in boxes lined with oil paper with a layer of wet moss on the bottom. The box is laid on its side during packing. When the box is full the oil paper is folded over the asparagus and the side boards are nailed on. The loose pack may include ungraded spears or only those that are difficult to bunch.

Packing.—Several types of packages are used for asparagus, the most popular one being a box having solid ends and made especially for this product. These boxes are made to hold one or two dozen bunches. A popular crate used in California is a pyramidal one with two compartments holding six bunches of 2½ pounds each. The inside dimensions of this crate are usually 10½ by 9½ by 17¹¹⁄₁₆ inches with outside length of slat of 19½ inches. A crate of the same size with a panel end is used in Georgia and South Carolina. A two-dozen size crate is used in some sections. One used to some extent in New Jersey has an inside measurement of 10½ by 14½ by 17 by 23⅜ inches and an outside length of slat of 25 inches. Other sizes and types of crates, including the 32-quart berry crate, are used but the tendency is toward the one-dozen size.

The boxes or crates usually are lined with paper to prevent excessive drying, or the bunches are wrapped with waxed paper. The latter method is common in California. A thin layer of damp moss often is put in the bottom of the crates and the butt ends placed on this.

Changes in Quality after Cutting.—Asparagus undergoes marked changes in structure and chemical composition after it is cut and the rate of these changes depends on the temperature. The most important changes concern growth in length and weight, in sugars and crude fiber. All of these changes are markedly influenced by the temperature at which the spears are kept after they are harvested. Bisson, Jones, and Robbins (1926) have shown that the spears grow in length if the butts are in water or are placed on moist moss. The growth rate was least at 33°F. and increased as the temperature was raised to 41°, 56°, 77°, and 95°F. The greatest increase in length occurred during the first 24 hours. There was an increase in weight also due to the absorption of water. Chemical analyses show a loss in reducing substances and in total sugars. The losses were especially pronounced at the higher temperatures. The maximum rate of loss occurred during the first 24 hours. Crude fiber increased during storage at all temperatures. The greatest increase in crude fiber at all temperatures was during the first 24 hours after the spears were cut, but was least at the lowest temperature and greatest at the highest temperature. Lignification took place throughout the length of the spear.

The results given above show the importance of getting the asparagus graded, bunched, packed, and cooled as soon as possible. Pentzer *et al.* (1936) have shown that precooling as soon as the car is loaded results in a marked reduction in temperature during the first 4 days in transit from California to Eastern markets. The average transit temperature of a pre-cooled car averaged 45°F. the first day and 47°F. the first 4 days, as compared with 61°F. and 56°F. respectively for the non-precooled car. Refrigeration was used in both lots. Precooling results in a reduction in transit refrigeration costs and, if well done, assures a satisfactory condition on arrival. Precooling was accomplished by fans that circulated the air in the car through the ice bunkers, reversing the natural circulation.

RHUBARB

Rhubarb is grown for its large, thick leafstalks or petioles, which are used for sauces and pies. It is used in the diet in the place of fruit. Since rhubarb is available early in the season it is a popular article of food.

In the home garden, the rhubarb bed should be located on one side or at one end along with the other perennials so that it will not interfere with preparation of the remainder of the area. Commercially, it should be planted in a block by itself or with other perennials for convenience in tillage operations.

The rhubarb plant is a herbaceous perennial, the underground portion of which consists of large, fleshy, and somewhat woody rhizomes and a fibrous root system. The first leaves grow from the crown and it is the petioles of these that are used for food. Later the flower stem develops and may grow to the height of 4 to 6 feet. This stem is hollow, has conspicuous nodes, and relatively small leaves. The flowers are numerous in successive panicles, small, greenish white in color, on slender pedicels. Self-pollination within the individual flower does not occur due to the fact that the anthers ripen and shed their pollen before the stigma is receptive (protandry). Pollen may fall from flowers on the upper part of the stem, which open later, to the stigmas of lower ones.

History and Taxonomy.—Rhubarb is a native of the colder portions of Asia, probably Siberia. It was introduced into Europe about 1608 and was first grown in Italy. According to Sturtevant, the first mention of its use in America was in 1778, but by 1806 it was in common use.

Rhubarb belongs to the buckwheat family, Polygonaceae, and to the genus Rheum, which contains perhaps 25 so-called species. The common cultivated rhubarb belongs to the species *Rheum rhaponticum L.*

Climatic Requirements.—The rhubarb crown and rhizomes are resistant to cold and to dry conditions. The plant thrives in regions where the crowns remain frozen all winter, and where the soil remains dry throughout the summer as in California. In regions where the summers are rainless or practically so, and the winters are mild, rhubarb grows during the winter and early spring and is dormant during the summer. In other regions the plant is dormant during the winter and grows during the spring and summer. A dormant period does not seem to be essential as the plant grows throughout the year in the Imperial Valley of California when irrigated as water is needed. The vegetative parts of the plant are killed at 26 or 27°F. At relatively low temperatures for growth, the stalks develop the pink color, while at high temperatures the green color predominates.

Rhubarb does not seem to grow well in most sections of the South, except at high altitudes where the climatic conditions are similar to those of regions much farther north. It has been assumed that the lack of a definite dormant period is the reason the crop is not grown in the lower South, but the fact that it grows throughout the year in the Imperial Valley indicates that some other factor is involved.

Soils and Soil Preparation.—Rhubarb is grown on many kinds of soil, but fertile sandy loams and silt loams are preferred. Heavy silts are used in some sections and clay loams in others. Where light soils are used they generally are manured heavily. Abundant moisture is needed during the growing season. In California the crop is grown mainly during the rainy season and remains dormant during the dry season.

The soil should be plowed to a good depth and then thoroughly prepared before the crop is planted.

Manures and Fertilizers.—Unless the soil is rich it should be well manured or fertilized. Where manure is available applications of 20 tons per acre may be used to advantage. In addition to the manure, some readily available fertilizer should be applied in the spring. Where manure is not used, heavy applications of commercial fertilizers are necessary. A fertilizer approaching a 1:1:1 ratio should give good results on sandy loam soils if applied so as to furnish 100 to 150 pounds each of the important fertilizing constituents. On rich silt and clay loams the rate of application might be reduced. A good growth of foliage after the harvesting season is essential to heavy yields the following season.

Manure should be applied during the winter and the fertilizer in the spring, or part in the spring and part at the end of harvest in regions where the dormant period is in winter.

Planting.—Rhubarb is grown mainly from division of the old plants because there is too much variation in the plants produced from seed. In dividing, the old crowns may be cut into as many pieces as there are good, strong buds. If seed is used, careful selection of plants should be made before setting them in the permanent bed in order to have plants of similar characteristics. The seed should be planted in the spring in rich, well-prepared soil; after the plants are well established they should be thinned to stand 3 to 4 inches apart in the row. One more year is required for producing a crop from seed than from division of the crowns. In most sections of the North planting usually is done early in the spring, although fall planting is practiced in the milder regions. Fall planting is advised where deep freezing does not occur, as in the regions from Maryland south as far as the crop can be grown. The pieces of roots are usually planted 3 to 4 inches deep in rows 4 to 6 feet apart and about 2 to 3 feet apart in the row. On very rich soils 3 by 5 or 3 by 6 feet distance should be used, especially for the Victoria variety which is more vigorous than the Linnaeus.

Cultivation and Care.—Clean, shallow cultivation should be given as often as necessary to control weeds. Before growth starts, the bed should be harrowed thoroughly, but with care to avoid injuring the crowns. It is desirable to apply the fertilizer at this time so as to mix it with the surface soil by harrowing. In some sections of California the rows are bedded with soil as soon as growth starts. The leaves grow up through several inches of soil, resulting in longer stalks and a good pink color.

Varieties.—There are relatively few varieties of rhubarb; those most commonly grown are Victoria, Linnaeus, and Mammoth Red. Recently two new varieties, the McDonald and Cherry Red, have become popular. The McDonald was developed at McDonald College in Quebec and has been tested in many parts of the United States and Canada. It is now being grown in many regions and is popular because of its red color. The Cherry Red is grown in California and other Pacific Coast states. The Victoria does not develop such attractive color as the other varieties, but is the most important commercially because of its large leaf stems and heavy yields.

Harvesting.—In regions with a fairly long growing season, rhubarb is harvested for a short period during the second year, and for the full harvest period in the third year. Where the growing season is relatively short, the first harvest is made at the beginning of the third season. For best results over a period of years the harvest period should not be longer than 8 to 10 weeks. Harvesting both in spring and in late summer is not advised except when the bed is to be discontinued. Usually after 10 to 12 years the plants become so crowded and the leaf stalks so small that it does not pay to maintain the old bed.

In harvesting, the stalks are pulled (not cut) and the leaf blades are cut off. The stalks usually are washed before being packed for market. For local markets the stalks often are tied in bunches of one pound or more, but for shipping they are packed in bulk in boxes lined with paper.

Forcing.—Rhubarb forcing on a commercial scale is a profitable enterprise in many sections of the North. The practices vary with different growers, but in general, the principles are similar. When the plants are grown exclusively for forcing, 2-year-old ones are preferred although some growers use 1-year-old roots. When forcing is a side line to outdoor production of rhubarb, older roots often are used. Experimental results reported by Sayre (1927) indicate that 3-year-old roots produce larger yields than younger ones. Roots 4, 5 and 6 years old produced substantially the same yields as those 3 years old.

With any method of growing and forcing, the roots are dug or plowed out late in the fall and left outside until they are thoroughly frozen, after which they are ready for forcing. When the roots are left out of doors to freeze, they should be covered lightly with soil, or with some other material to prevent too rapid evaporation of moisture. Freezing seems to be essential, but Sayre's results show that light freezing is better than severe freezing. He found that severe freezing (2 weeks at −10°F.) was injurious and reduced the yield, while brief thorough freezing, followed by a rest period, was as effective as freezing throughout the dormant period. On this point Sayre reports as follows:

> Soon after digging in the fall, roots of various ages were frozen for 2 weeks in cold-storage chambers at 20°, 10°, and −10°F. Half of each lot of roots was then forced immediately. The remainder of each lot was kept dormant for an additional month before forcing. Regardless of the freezing temperature, the roots of each lot which received the longest rest period, produced a two- to threefold greater yield and made a more rapid growth than roots which had not been given the rest period. Severe freezing was not effective in shortening the rest period needed for maximum growth.

Rhubarb may be forced in ordinary cellars, in hotbeds, cold frames, under greenhouse benches, in specially constructed forcing cellars, or in any moderate-temperature, dark, or semidark location. The roots are placed on the floor of the forcing place, as close together as is feasible, and are then covered with soil to the depth of 2 or 3 inches. The soil should be worked down between the clumps and around the rhizomes, and should be kept moist, but not wet. A temperature of about 60°F. is considered right. At higher temperatures the crop is earlier, but the color and quality are not so good as when the crop is forced at lower temperatures. At temperatures around 50°F. growth is too slow. Light is not essential or desirable. When grown in darkness or semi-darkness, the stems develop a good color and good quality and the leaf blade expands very little.

ARTICHOKE

The artichoke, or globe artichoke (*Cynara scolymus*), is a herbaceous perennial plant grown for its flower head or flower bud. It is a coarse, thistlelike plant of the sunflower family, native of the Mediterranean region, and common in the wild form in Southern Europe and in Northern Africa.

The aboveground portion of the plant dies down each year and the crowns of individual plants decay after a year's growth, but are renewed by offshoots from the rootstocks. The flowers are borne terminally on the main stem and the laterals. The edible portion consists of bracts which are fleshy at the lower end. The plant grows to the height of 4 to 5 feet and bears several buds.

This vegetable is highly prized in France and other European countries, but has not become popular in the United States, although it has been grown to a limited extent in the South for over a hundred years.

The plant will stand temperatures several degrees below freezing, but is grown mostly in regions having mild winters. As a market crop, the artichoke is grown mainly near the coast in California with the largest acreages in Monterey, Santa Cruz, and San Mateo counties, south of San Francisco. Although the plant will stand temperatures several degrees below freezing, if freezing occurs during the growing period the plants will be injured or killed. On the other hand, hot weather causes the buds to open thereby reducing the tenderness of the edible portion.

The artichoke will grow on a wide range of soils, but it produces best on a deep, fertile, well-drained soil. According to Tavernetti (1933) it is important to keep the soil well supplied with organic matter. Many growers apply 10 to 12 tons of manure to the acre immediately after the stalks are cut in the summer. Nitrogenous fertilizer is applied at the rate of 60 to 85 pounds of nitrogen to the acre, as sulphate of ammonia, nitrate of soda, or other carrier, just before harvesting begins.

Propagation.—While the artichoke can be grown readily from seed, the plants do not come true. Vegetative propagation by means of suckers or offshoots from the rootstock is the method used. It is desirable to select shoots from plants of known productivity and other desirable characteristics. They are usually selected and removed when 12 to 18 inches high and care is taken to save as large root systems as possible.

Planting and Care of the Crop.—In California planting is done during the fall and winter. The distance of planting varies, depending on the fertility of the soil and the methods of culture. Tavernetti states that the rows usually are 8 feet apart and the plants 6 feet apart in the row in California, although these distances vary somewhat. The plants are set 6 to 8 inches deep.

The crop in California is irrigated several times (usually three to five) during the growing period, the first irrigation being applied in early summer to start growth for fall harvest. The furrow method of irrigation is the most common.

Clean cultivation is given as needed during the growing season. After each irrigation the soil between the rows is disked or harrowed to kill the weeds and to smooth the surface. After the last harvest in spring, the stems are cut off below the level of the ground. There are three different methods of disposing of the old stems and leaves. Some growers make silage of them, others place them in a dead furrow between the rows and cover them over, and still others allow them to dry and then burn them.

In regions where heavy freezing occurs some covering is necessary to protect the crowns. Wellington (1917) found that covering with coal ashes in November and removing it in March or early April was a satisfactory method at Geneva, N. Y. Manure covering was very unsatisfactory, resulting in rotting of the crowns.

According to Tavernetti, maximum production occurs during the second and third years following planting. After about four years, it is usually found desirable to renew the planting.

Harvesting, Grading, Packing, and Marketing.—Harvesting begins when the first buds reach maturity in the fall and continues until spring, the peak coming in early spring. The buds are harvested before they become loose and fibrous. The stem is cut an inch or an inch and a half below the base of the bud. The buds are separated into five or six sizes, usually by machine graders, then they are graded for quality. They are then packed in layers in paper-lined boxes of three sizes: large, 9¾ by 11 by 20⅝ inches; half size, 4⅞ by 11 by 20⅝; and a box used for local shipments, 8½ by 14 by 22⅜. The large and half-size boxes are used for long-distance shipments. Large buds are the most desirable.

For long-distance shipments refrigerator cars are used with the usual icing. Most shipments are in mixed cars with lettuce and other vegetables.

JERUSALEM ARTICHOKE

The Jerusalem artichoke (*Helianthus tuberosus*) is a herbaceous perennial arising from fleshy rootstocks that bear oblong tubers. When grown under cultivation it is handled as an annual. This plant belongs to the compositae family and is a native of North America, where it was grown by the Indians at the time the early settlers arrived in the United States.

The Jerusalem artichoke has been recommended in the past as feed for hogs and as a garden vegetable, but has not become popular for either use. Recently it has aroused interest because of the possibility of producing levulose sugar commercially from the tubers. Levulose (fructose) or fruit sugar is sweeter than cane sugar and very much sweeter than dextrose (glucose). Heretofore it has been difficult to crystallize and has been made in crystalline form only in small quantities and at high costs. New and improved methods of producing levulose from artichoke tubers have been announced by the Bureau of Standards.

The carbohydrate inulin is stored in the tubers of Jerusalem artichoke and inulin on hydrolysis yields levulose. Levulose bears the same relation to inulin that dextrose bears to starch. Levulose is of interest because of its supposed value in the diet of persons suffering from diabetes.

The Jerusalem artichoke is adapted for production over a wide range of climatic and soil conditions. It is grown in most parts of Europe, in parts of Asia, and throughout the temperate regions of the Southern Hemisphere. It can be grown in all parts of the United States.

Culture.—The Jerusalem artichoke will grow on all kinds of soils but does not thrive in a wet soil. It will grow better on poor soils than most crops. In France this crop is planted on soil too poor for potatoes or beets. Of course, larger yields are obtained when the crop is grown on good soil than when grown on poor soil. Sandy or sandy-loam soil has the advantage over heavier soils of not adhering to the tubers when they are dug.

Little is known about the fertilizer requirements of the Jerusalem artichoke, but results of French and German experiments indicate that potash is important. The fertilizer practice followed for potatoes would probably be satisfactory for this crop.

Planting may be done in the fall at harvest time or at any time in the spring before growth begins. In most sections of the United States probably spring planting would be best. The tubers are planted either whole or cut as are potatoes. The distance of planting varies considerably, depending on the richness of the soil and the region in which the crop is grown. In regions where the plants do not grow large because of the climate less space is needed than in regions where they do grow large. Shoemaker (1927) found that planting the tubers 18 to 20 inches apart in the rows 3.3 feet apart at Washington, D. C., was very satisfactory. He also suggests that the space commonly given to field corn would be satisfactory for the Jerusalem artichoke. Where the whole tubers of the smaller sizes are used for planting 6 or 7 bushels are required per acre.

Less cultivation is required for the Jerusalem artichoke than for most cultivated crops as the plants choke out weeds. Little or no hand weeding and hoeing are required.

Harvesting.—Little attention has been given to harvesting this crop as it has been used largely for hog feed where it has been grown in the United States. The hogs do the harvesting for themselves. Where the Jerusalem artichoke is used for human food the tubers are dug by hand as needed. With large-scale production some digging machine would be essential and it is probable that the potato digger would be satisfactory. It probably would be necessary to cut the plants before digging in regions where the plants grow 8 to 10 feet high.

SEA KALE

Sea kale (*Crambe maritima*) is a hardy perennial of the Cruciferae or mustard family, native of western Europe. It is grown for its young leaves and shoots, which are blanched with earth or with a sea-kale pot. A large flower pot, with the hole in the bottom plugged, will serve the purpose of a regular kale pot.

Sea kale may be propagated by seeds or by cuttings. When seeds are used they are planted in a well-prepared seedbed to the depth of about 1 inch. After the plants are well up they are thinned to 5 or 6 inches apart in the row and given good cultivation and care during the season. The following spring they are taken up and planted in the permanent bed. When cuttings are used, pieces of roots 4 to 5 inches long are planted in their permanent location early in the spring, spaced 3 feet each way.

The bed should be well fertilized each year, either with manure or with chemicals. The care of the bed should be about the same as described for rhubarb. At the close of the season the dead leaves are cleared away and the crowns of the plants are covered with a mulch of compost or manure.

Shoots from plants which have made a strong growth may be harvested for a short period during the second season, but a full crop should not be taken until the plants are three years old. The young shoots are cut when 4 to 5 inches tall and used much in the same manner as asparagus. The cutting season usually lasts 3 to 6 weeks. This vegetable is popular in England but is little grown in the United States.

CHAPTER XVII

POTHERBS OR GREENS

SPINACH
NEW ZEALAND SPINACH
ORACH
CHARD
KALE
MUSTARD
COLLARDS
DANDELION

Potherbs, or greens, are grown for their foliage; their culture is relatively simple. Most of them will withstand freezing temperatures and are grown mainly in the cooler parts of the growing season. Chard and New Zealand spinach are exceptions; they are relatively tender and are grown during the summer in the North. Spinach is the only crop in the list that is grown on a large scale for shipment to distant market and for canning and freezing.

To the plants listed many others might be added. Some crops used for greens such as turnips, beets, and sea kale are discussed in other chapters. Many wild plants such as dandelion, several species of docks, lamb's-quarters, wild cress, pokeweed, milkweed, and others are used as greens.

The need for green food has been greatly emphasized during recent years due to the increase in knowledge of the value of the essential salts found in green plants and especially because such plants are rich in vitamins.

SPINACH

Spinach (*Spinacia oleracea*) is the most important of the potherbs grown in the United States and has increased greatly in importance during recent years. According to estimates by the U. S. Department of Agriculture (*Agricultural Statistics*, 1938) the commercial acreage of spinach increased from 13,680 acres in 1919 to 106,340 acres in 1937. In the latter year the acreage grown for market was 76,620 acres and that grown for manufacture was 29,720 acres. The acreage, production, and value of the commercial crop are shown in Tables XXIII and XXIV.

In 1937 the leading states in the production of spinach for market were: Texas with 50,000 acres, nearly two-thirds of the total; Virginia, second with 6,800 acres; New Jersey, third with 3,000 acres. The figures given in Table XXIII do not include all of the spinach grown, but only the commercial crop produced in 14 of the important states. Many other states produce some spinach for local markets.

California was the leading producer of spinach for manufacture in 1937 with 16,720 acres, over half of the total, and Texas was second with 8,000 acres. Quick freezing of spinach has developed rapidly in recent years.

TABLE XXIII.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF SPINACH GROWN FOR MARKET BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield per acre, bushels	Production, bushels (000 omitted)	Price per bushel	Value (000 omitted)
1918–1922	11,854	352	4,177	$0.67	$2,788
1923–1927	28,742	344	9,891	.54	5,319
1928–1932	48,040	263	12,650	.46	5,864
1933–1937	66,326	185	12,302	.41	5,034

The marked increase in the production and consumption of spinach probably is due largely to the fact that its value in the diet is becoming better understood. Consumption of nearly all kinds of green vegetables has increased enormously in recent years. Spinach is rich in minerals and in vitamin A and contains vitamins B, C and G. It is important also as a roughage, which aids in cleaning out the stomach and intestines.

TABLE XXIV.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF SPINACH FOR MANUFACTURE, 1919 TO 1937

Years	Acres	Yield per acre, tons	Production, tons	Price per ton	Value (000 omitted)
1919–1922	6,285	4.38	27,550	$25.44	$701
1923–1927	11,278	4.41	49,780	19.91	991
1928–1932	11,110	4.75	52,740	15.87	837
1933–1937	19,462	2.66	51,760	12.93	669

Plant Characters.—The spinach plant, soon after germination, develops a rosette of leaves from a much shortened stem near the surface of the ground. When the plant reaches a certain size, under favorable conditions, the stem begins to elongate and lateral branches arise from the axils of the rosette leaves. Secondary lateral branches arise from the leaf axils of both the central and lateral stems. The flower clusters are borne axially on both the larger stems and on the smaller branches. Rosa (1925) states that flowering usually begins on the middle portion of the larger stems and proceeds toward the base and the top. From 6 to 12 flowers develop in each cluster, but they do not all develop at the same rate.

While spinach usually is dioecious, occasionally monoecious plants are found. Rosa has described four types of plants with reference to sex expression and these he terms (1) extreme males, (2) vegetative males, (3) monoecious, and (4) females. The monoecious plants may be predominately staminate, predominately pistillate, or purely pistillate early but with some staminate flowers later, or almost equally staminate and pistillate throughout the season.

Rosa's experimental results indicate that environmental influences have no effect on sex expression. In general culture the ratio of staminate and pistillate plants is 1:1. The male plant dies after flowering, while the female continues to develop and ripen its seed.

Climatic Requirements.—Spinach thrives best during relatively cool weather and will withstand freezing better than most vegetable-crop plants. In regions having mild winters the crop is grown mostly during the winter and early spring, while in other regions it is grown both as a spring and as a fall crop. Spinach does not do well during hot weather. The length of day has a marked effect on its development. Garner and Allard (1920) found that lengthening the period of light artificially during the short days of late fall resulted in flowering within a few weeks. Plants from seed sown November 1, when grown under artificial light for 6 hours, in addition to normal daylight, blossomed between Dec. 8 and 23, while those that had only daylight had no blossoms as late as Feb. 12. It is well known that most varieties of spinach shoot to seed in the spring or early summer, often before reaching full market size, This probably is a response to length of day rather than to relatively high temperature as was formerly believed.

Soil Preferences.—Spinach can be grown on any good soil, but for an early spring crop a sandy loam is preferred and this type is also used for the fall crop. Rich loams and silts are considered good also. In some sections of the North, spinach is grown to a considerable extent on muck soil and this is considered excellent, especially when the crop is grown for canning. When the crop is grown on muck soil there is less grit in the canned product than when the crop is produced on mineral soils. The soil for spinach should be rich and fairly moist but well drained.

Good drainage is important, especially in regions where the crop is grown during the wettest part of the year. In the region around Norfolk, Va., the land is bedded up in low flat beds 5 to 6 feet wide with spaces 18 to 24 inches between beds, mainly to insure drainage.

Soil Reaction.—Spinach is known to be susceptible to injury by high acidity, or to conditions accompanying acidity, such as aluminum toxicity.

Zimmerley (1926) reported results of experiments at Norfolk, Va., in which optimum growth was at soil reactions between pH 6.0 and pH 7.0. He found marked retardation in growth at lower pH than 5.5; Wessels (1932) reported similar results from experiments on a silt-loam soil on Long Island. In the Long Island experiments, the yield of spinach was less than half as much on plots with a reaction of pH 5.0 as on plots with pH 6.0 to pH 6.3. At Norfolk and on Long Island there was practically no growth at pH 4.5 and most of the plants died in the seedling stage. Burgess and Pember (1923) attribute the injurious effects of acid soils to aluminum toxicity rather than to the H-ion concentration in itself. Under some conditions chlorosis develops when spinach is grown on soils that are only slightly acid, neutral, or alkaline. McLean and Gilbert (1925) reported chlorosis on spinach grown as a spring crop in Rhode Island soils with reaction values between pH 6.2 and pH 6.9. Zimmerley also reported chlorosis of spinach in alkaline soils in Virginia, but states that none was observed where the crop was grown on soils more acid than pH 6.5. McLean and Gilbert attributed chlorosis to lack of available manganese on alkaline or slightly acid soils and were able to overcome this condition by spraying the plants with 0.004 per cent manganous sulphate solution. Zimmerley found that the use of manganous sulphate was effective in reducing chlorosis only during the early stages of the trouble. Where the entire plants were yellow, the treatment was of no apparent benefit.

Considering all of the experimental data, it would seem that completely neutralizing the acidity is not desirable. On the other hand, where the soil is more acid than pH 5.5 (and possibly pH 6.0) liming probably would prove beneficial.

Manures and Fertilizers.—In most regions where spinach is grown on a large scale little fertilizer is used. Hawthorn (1932) reported that on the rich alluvial soils of southern Texas, growers rarely used fertilizers but were using new land that had not been impoverished by cropping. It is probable that with continued cropping it will be necessary to use fertilizer to maintain profitable production. Many market gardeners in the North use manure for spinach or for the crop preceding it. When fresh manure is used, it is best to apply it to the crop preceding spinach on account of weed seeds in the manure. Well-rotted manure may be applied to the land a short time before planting the spinach seed.

Commercial fertilizer is used in fairly large quantities in growing spinach in most parts of the United States, except in Texas and in California. If manure is not used, the fertilizer for sandy and sandy-loam soils should supply 100 to 125 pounds each of nitrogen, phosphoric acid (P_2O_5), and potash (K_2O). On silt loams and clay loams, both nitrogen and potash may be reduced. Where manure is used, the quantity of nitrogen and potash might be reduced by half. Many spinach growers apply all of the fertilizer after the crop is planted, making several applications. Zimmerley's results indicate that part of it should be applied before the crop is planted. From these results it would seem desirable to apply from one-half to two-thirds of the fertilizer before planting the crop and the remainder as top dressing on sandy or sandy-loam soil. On heavier soils it would seem to be unnecessary to make more than one application, especially where the crop is planted in the spring.

Planting.—Spinach is planted for a winter crop in the South and in California, while in most other sections it is planted mostly in late summer for fall use and very early in the spring for the early summer market, although in some areas in the North and on the Pacific coast the crop is grown throughout the summer. For the winter crop in Texas the seed is planted from September to January and in cooler sections of the South it is planted in February for spring use. In the North the early crop is planted as early in the spring as it is safe to work the land. Seed for the fall crop in the North is planted usually in late summer.

The rate of seeding varies greatly depending on the method of production and the distance between the rows. Hawthorn states that when the seed is sown broadcast on irrigated land in Texas the rate is 8 to 10 pounds to the acre, but when sown in rows the rate is 4 to 6 pounds. In many other regions, heavier rates of seeding are used ranging from 15 to 30 pounds according to the spacing of the rows, which varies from 7 inches to about 24 inches apart. In the vicinity of Norfolk, Va., the rows are spaced about 10 inches, while in other regions the spacing is 12 to 15 inches between rows for hand cultivation or for special power cultivators.

In the home garden spinach seed is usually planted by hand, but in commercial plantings seed drills are used. Gang drills, four or more drills attached to a common frame, are used by growers in many sections.

Spinach generally is planted on the level except where grown under irrigation or when grown as a winter crop in the South. Around Norfolk Va., low flat beds are used, each being planted to 4 rows, 10 inches apart.

When spinach is grown under furrow irrigation, narrow beds are used on which one or two rows are drilled.

Thinning.—When spinach is grown on a large commercial scale thinning is seldom practiced, but in some regions the plants are thinned to stand 4 to 5 inches apart in the row. Where thinning is not practiced, the spacing should be regulated by adjusting the rate of seeding. Thinning can be done readily by using a narrow, sharp hoe to cut out the plants. The main advantage derived from thinning is the development of large, uniform plants. The main disadvantage is the cost involved. In the home garden the common practice is to remove the argest plants as soon as they get large enough for use and to continue his operation until the plants have sufficient space for full development.

Cultivation.—Clean, shallow cultivation is given spinach, accomplished vith hand cultivators, or with horse-drawn or tractor-drawn implements. n muck soils the scuffle hoe and the wheel hoe with blade attachnents are used to a considerable extent. At Norfolk, Va., novel weederike cultivators are sometimes used and one horse or one mule pulls wo of the implements as shown in Fig. 17. The horse or mule walks in he space between the beds so that there is no danger of injuring the lants by tramping on them. Garden tractors may be used in place of and cultivators or horse-drawn implements.

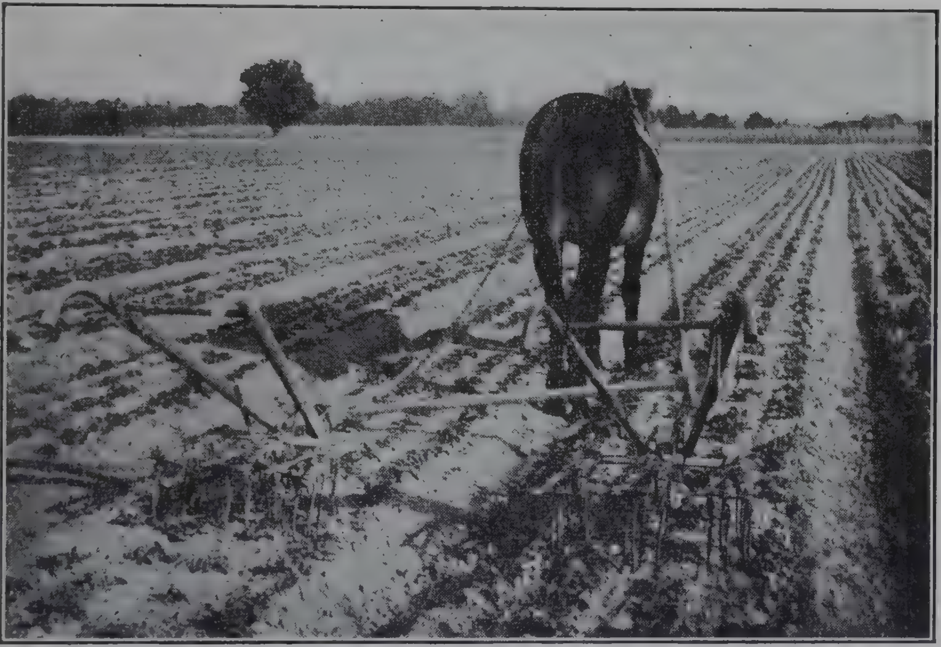

FIG. 17.—Two cultivators fastened together for use in cultivating spinach on raised beds in the vicinity of Norfolk, Virginia. (*Courtesy of Va. Truck Exp. Sta.*)

Varieties.—The varieties of spinach now being grown are not very different from those studied by Goff (1887) and by Kinney (1896). Kinney collected and studied all of the available varieties. He classified them into four groups as follows:

Group 1. Norfolk or Bloomsdale.
Group 2. Round-leaved.
Group 3. Thick-leaved.
Group 4. Prickly Seeded.

Jones and Rosa (1928) reported tests of 121 varieties obtained from American and European sources and concluded that there are only five distinct varietal types, one of which they believed had been developed since Kinney had made his studies. Geise and Farley (1929) and Drewes

(1932) also described the varieties and followed in a general way the classification given by Jones and Rosa. Geise and Farley classified varieties into two classes or groups: A, Flat-leaved type; and B, Savoy-leaved type. Each of these classes was subdivided into three groups as follows: I. Short Season Group; II. Long Standing Group; and III. Slow Growing Group. More recently Magruder *et al.* (1938) published a classification and description of the principal American varieties of spinach. This classification is as follows:

A. Leaves savoyed
  B. Leaves heavily savoyed
    C. Plants late seeding
      D. Leaves blue-green—Juliana
      D.D. Leaves dark green—Long Standing Bloomsdale
    C.C. Plants not late seeding
      D. Plants very early seeding—Virginia Savoy
      D.D. Plants medium early seeding—Dark Green Bloomsdale
  B.B. Leaves medium savoyed—Old Dominion
A.A. Leaves not savoyed (or slighted savoyed in cool weather)
  B. Plants early seeding
    C. Seeds prickly—Hollandia
    C.C. Seeds not prickly—Viroflay
  B.B. Plants not early seeding
    C. Seeds prickly—Amsterdam Giant
    C.C. Seeds not prickly
      D. Leaves blue-green—King of Denmark
      D.D. Leaves medium green—Nobel

The varieties of spinach studied by Magruder *et al.* were grown and described at Ithaca, N. Y. (2 years); Arlington, Va., and Beltsville, Md. (5 years and seven crops); Winter Haven, Tex. (three crops); and Davis, Cal. (five crops). Complete descriptions and brief characterizations of the important varieties are given by Magruder *et al.* Since new varieties come on the market from time to time and some of the old varieties are discarded, it does not seem worth while to describe them here. Figure 18 illustrates the foliage characters of some of the typical varieties as grown at Ithaca, N. Y.

Spinach Blight or Yellows.—This is a virus disease and is very serious in many spinach-growing sections. Plants affected by it show a light yellowing and malformation of the young leaves in the early stages. In later stages the plant stops growing and the leaves are mottled. Some of the older leaves may turn brown and wither. Leaves of affected plants are slightly brittle and the blade curves backward toward the base of the plant.

McClintock and Smith (1918) have shown that the disease is carried from diseased to healthy plants by insects, especially the aphis. It was hought that spraying or dusting to control this insect would control the disease, but destroying the insect has not proved practicable.

The most feasible means of controlling yellows is by growing yellows-resistant varieties such as Virginia Savoy and Old Dominion, developed by the Virginia Truck Experiment Station. The Virginia Savoy was developed from a cross between a type obtained from Manchuria (Manchukuo) by F. N. Meyer, and the Norfolk Savoy.

Downy Mildew.—This disease is caused by *Peronospora effusa* and is prevalent in all regions where spinach is grown. The disease on the leaves is manifested by pale yellow spots which may cover the entire leaf. On the lower side of the leaf the lesion is covered with a mold, gray to violet-gray in color. The affected part finally decays or dries, and the whole leaf dies. In severe cases the whole plant dies.

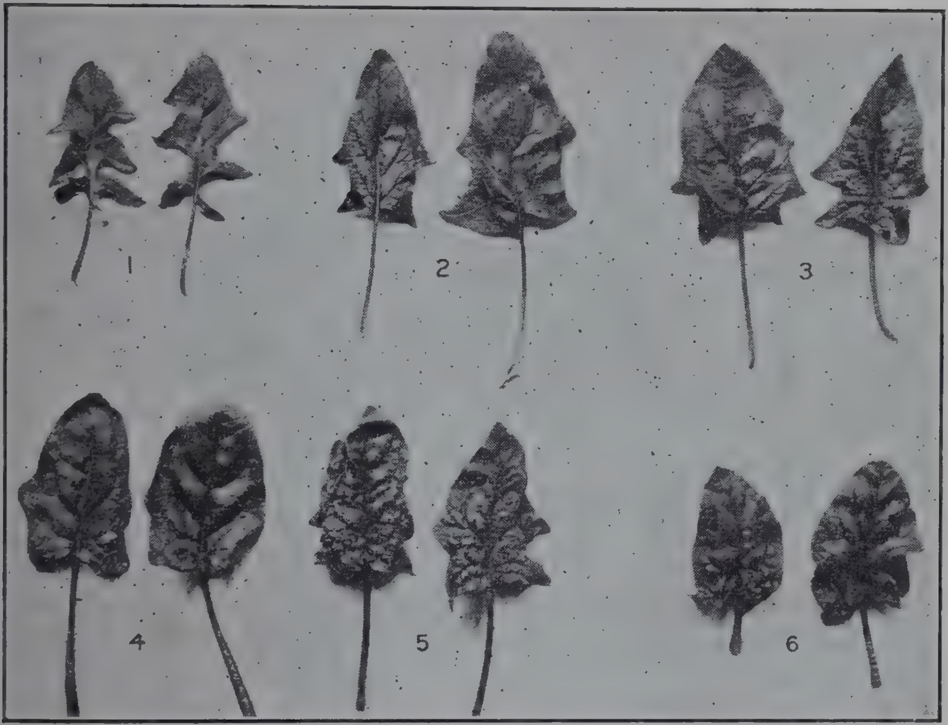

FIG. 18.—Typical leaves of varieties of spinach: 1, Horenso (unimportant); 2, Giant Thick Leaf or Eskimo; 3, Long Standing; 4, King of Denmark; 5, Savoy; 6, Victoria.

Correction of any unfavorable environmental conditions is important in the control of this disease. Good drainage, weed control, preventing crowding of the plants, and good fertilization are important.

Heterosporium Leaf Spot.—This is an old disease and is found almost everywhere spinach is grown. The disease appears as small brown spots, which enlarge and multiply until so much of the leaf is affected that the remainder turns yellow and dies. Greenish-black mold appears in the spots on both surfaces of the leaf.

No definite control measures are recommended except to keep the plants in a thrifty growing condition by good cultural practices.

Other Diseases.—In addition to the three diseases mentioned, there are others that are of importance under some conditions. These include Cercospora leaf spot, anthracnose, fusarium wilt, rust, scab or black mold, smut, crown rot, damping-off, and root knot. Damping-off can be controlled by seed treatment. Horsfall (1938) reports that control has been obtained by treating the seed with copper or mercurial fungicides. He obtained the best results by soaking the seed for an hour in a one per cent solution of copper sulphate, or shaking the seed with red copper oxide until the seed was thoroughly coated, using about one level teaspoonful of powder to one pound of seed. The control of root knot is discussed under "Cabbage." Control measures for the other diseases mentioned have not been devised, except the following of good cultural practices.

Spinach Aphis (*Myzus persicae*).—This insect is a pale yellowish green plant louse that often causes serious injury to the spinach crop. It injures by sucking the juice out of the leaves and also carries spinach blight from diseased to healthy plants. Since this insect lives largely on the underside of the leaves it is very difficult to control by spraying. It is claimed by Smith (1920) that the Manchuria spinach is distasteful to the spinach aphis, and that these insects are much less abundant on the Virginia Savoy than on the commercial Savoy.

The most practical control measure is dusting with (1) a 2 or 3 per cent nicotine-lime dust or (2) a $\frac{3}{4}$ of 1 per cent or 1 per cent rotenone dust. It is necessary to have the nozzles of the duster carefully adjusted close to ground and to use a canvas trailer to confine the dust. For best results, the plants should be dry, the temperature above 70°F., and the air movement very slight.

Beet Leaf Miner.—(*Pegomyia hyoscyami*).—This insect is a serious pest of early spinach in many sections of the United States. For discussion see under "Beet."

Harvesting.—Spinach may be harvested from the time the plants have five or six leaves until just before the seed stems develop. Of course, a larger yield is obtained if the plants are allowed to develop to full size than if cut when they are small. Medium- to large-sized plants are preferred, if the leaves are tender.

Spinach should be harvested by cutting the tap root just below the lower leaves. The cutting may be done with a long, sharp knife, with a hoe, with the blades of a hand cultivator, or with a special homemade tool similar to the one shown in Fig. 19. This tool has a long handle with a crosspiece on the end and is pushed in front of the operator like a lawn mower. Spinach is often gathered with forks, placed in large crates or baskets, and loaded on trucks or wagons, or it may be loaded in bulk. Placing the spinach in baskets or crates is preferable to loading in bulk, since by the latter method extra handling with forks increases the injury.

Some trimming is usually necessary to remove all of the dead and discolored leaves. This may be done in the field or in the packing shed. If the crop is grown for the cannery the trimming is done at the factory.

It is best not to cut spinach immediately after a rain or heavy dew because the leaves are crisp and brittle and break easily when wet. A slight wilting will prevent any breaking of the leaves.

Preparation for Market.—Spinach is often washed to remove sand and dirt and to improve its appearance. Ridley (1921) found that washed spinach developed a greater amount of decay after holding 10 days under approximate transit conditions than unwashed spinach under the same conditions. The lots that were washed developed 37.3 per cent soft rot, while those not washed developed only 7.7 per cent. In shipping tests, where the period in transit was from 3 to 6 days, the soft rot found in washed spinach on arrival was 5.5 per cent and in unwashed spinach 0.0. Three days later the washed spinach showed 24.8 per cent decay and the unwashed 5.7 per cent. For local markets and for short hauls there is no objection to washing, but for long hauls it may be harmful. The plants are likely to be bruised and the leaves broken to some extent in the process and decay is thereby increased. The decay is materially reduced by placing crushed ice in the top of the container and shipping under refrigeration.

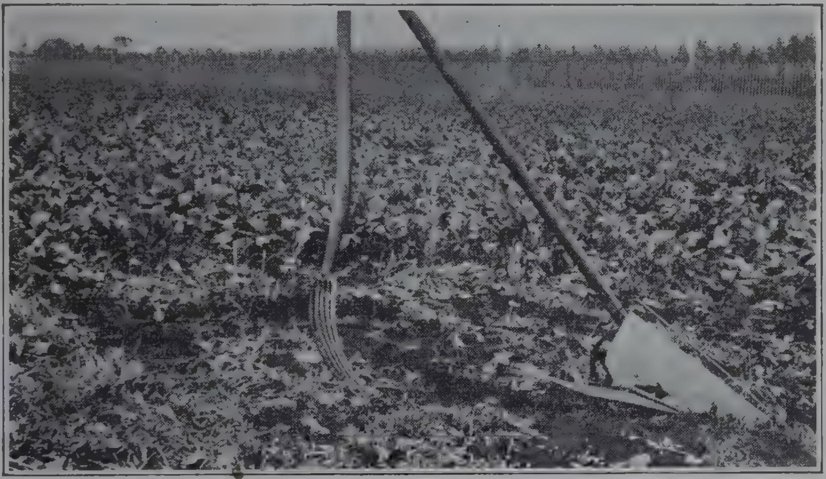

FIG. 19.—A homemade tool for cutting spinach.

Spinach is packed for shipment in various types of containers including the round bushel basket, hamper, and crate. For long-distance shipping, as from California, Texas, and Louisiana, crushed ice is put in the package. As a rule the quantity of ice used is from two-thirds to three-fourths of the weight of the spinach. Ridley has shown that when part of the ice is put on top of the spinach much better results are obtained than when all of the ice is placed in the center of the basket. In one car shipped from Austin, Tex., to Chicago temperatures of the spinach were taken above and below the ice at frequent intervals during the trip. The temperature below the ice averaged about 35°F. for 3½ days, while above the ice the temperature at the beginning was above 60°F. and gradually dropped to about 42°F. The average difference was over 10° for the period.

NEW ZEALAND SPINACH

New Zealand Spinach (*Tetragonia expansa*) is not a true spinach but belongs to a different family, Aizoaceae. The leaves resemble spinach leaves to some extent and the product is used in the same way. The plants are much branched, spreading often 3 or 4 feet across, and grow to the height of 1 to 2 feet. The leaves are thick, dark green, and somewhat triangular in form. The seeds are enclosed in a hard rough pod.

New Zealand spinach thrives in hot weather when ordinary spinach will not grow satisfactorily. It is not seriously injured by the leaf miner and does not go to seed quickly. The tips of the branches are harvested for food and since these do not come in contact with the soil there is no sand or soil to be washed off and no waste in preparing for the table.

Culture.—Seed may be planted in a greenhouse or hotbed during late winter. The plants should be pricked out while still small, preferably into pots, so that they can be set out later without disturbing the roots to any great extent. These plants should be set 2 to 3 feet apart in rows 3 to 4 feet apart, but only a few plants are required for a family of five. Commercially, the seed is sown in the open in rows very much like spinach, but more space must be given. New Zealand spinach is not so hardy as spinach, therefore, it should be planted later in the spring.

Harvesting.—When grown for home use, the tips of the branches, 3 to 4 inches long, are snipped off. This is continued throughout the season. When grown for market, a more common practice is to cut off the entire plant 2 or 3 inches from the surface of the ground. A bunch is grasped in one hand and is cut off with a large, sharp knife held in the other hand. Two, three, or more cuttings are made in this way. The product is handled in much the same way as spinach, for which it is a substitute. The main harvest period is during the summer when spinach is not available.

ORACH

Orach or mountain spinach (*Atriplex hortensis*) has long been used as a kitchen-garden vegetable in Europe, but is rarely grown in the

United States. It belongs to the family Chenopodiaceae. The plants grow to the height of 4 or more feet and have many lateral branches. There are three types based on the color of the leaves: the white variety has pale green leaves; the green variety has rounder leaves than the white and is slightly more vigorous; the red variety has stems and foliage of dark red color. The color disappears when the leaves and stems are cooked.

The seed is planted in the open early in the spring in rows 18 to 24 inches apart and the plants thinned to stand 10 to 12 inches in the row. The plants are used while young and tender, and although they stand hot weather fairly well, they soon run to seed; therefore, for a continuous supply, successive plantings should be made at intervals of two weeks until summer weather arrives.

The general culture of orach is about the same as for spinach for which it is a substitute.

CHARD

Chard or Swiss chard (*Beta vulgaris* var. *Cicla*) is a foliage beet which has been developed for its large, fleshy leafstalks and broad, crisp leaf blades. It is one of the best potherbs for summer use since it withstands hot weather better than most greens. The leaves are prepared for the table like spinach, while the leafstalks and midribs are often cooked and served like asparagus. Chard is not so rich in iron as spinach, but is a good addition to the list of potherbs and deserves more general planting, especially in the home garden. It may be canned in the same manner as spinach.

Culture.—Chard is easily grown. The plants may be started in the greenhouse or hotbed and transplanted to the open as soon as the danger of hard frosts is over, or the seed may be sown in the garden or field where the plants are to grow. The rows should be about 18 inches apart for hand cultivation, and 30 to 36 inches for horse-drawn cultivators. When the plants are set out they should be spaced 10 to 12 inches apart, and when seed is sown in the garden the plants are at first thinned to 3 inches and later when they begin to crowd they are thinned to 8 to 12 inches apart in the row. The plants removed may be used as greens.

A planting made in the spring will produce greens throughout the season until hard freezes occur and with a little protection the plants will live throughout the winter. Any good garden soil is satisfactory for chard. Unless the soil is rich and well supplied with humus a medium application of manure is desirable. Where manure is not available, a green-manure crop may be used to supply humus. In addition to manure an application of a little readily available nitrogen, and about

500 pounds of superphosphate to the acre is advised. Where no manure is used, a complete fertilizer should be applied on most soils.

Chard is grown to some extent as a forcing crop in greenhouses.

Varieties.—There are only a few varieties, the most important one being Lucullus, which has very large crumpled, dark-green leaves, with greenish-white leaf stems. Giant Perpetual has broad light-green leaves. Lyon, a new variety selected for its broad stem and midrib, is listed by some seedsmen. Large Ribbed White has broad, white stalks and white midrib. The varieties are not very distinct and it is probable that many of the names are synonyms, but Lucullus represents the type most commonly grown.

Harvesting.—The usual method of harvesting for home use is to cut off the outer leaves an inch or two from the ground while they are still tender, using a large, sharp knife. Care should be taken to avoid injuring the bud. For market, a more common method of harvesting is to cut off all of the leaves above the growing point in the center. Subsequent harvestings are made in the same way when the leaves reach marketable size. The leaves often are bunched and tied in preparation for market and the product sold by the bunch or by the pound. Chard, however, is not an important market vegetable.

KALE

Kale (*Brassica oleracea* var. *acephala*) apparently has decreased in importance in recent years. The U. S. Department of Agriculture gives the average acreage for the years 1928–32 in the Norfolk, Va., region as 1,920 acres; for 1936, 1,300 acres; and for 1937, only 1,050 acres. This is the only region listed in "Crops and Markets." In the region mentioned, kale is grown during the winter and early spring and is shipped to eastern markets.

Kale is hardy to cold but does not thrive in hot weather, hence it is seldom grown as a summer crop.

Kale has been under cultivation for a very long time. It was known to the ancient Greeks. Several varieties were described by Cato, who lived about 200 B.C. It was known in the United States during the seventeenth century.

Many types of kales are known, but they all probably belong to the same species. The chief characteristics of all are that the plants do not form heads like cabbage or produce edible flowers like cauliflower and broccoli. Some are grown as ornamentals, being variously curled and of beautiful colors.

Soils and Fertilizers.—Kale will thrive on any good garden soil, but a well-drained sandy loam is considered best. The soil should be well prepared as for any other vegetable crop.

Kale is a fairly heavy feeder and unless the soil is rich it should be liberally fertilized. In the Norfolk, Va., region growers apply a ton or more medium-grade fertilizer per acre, and in some instances manure also. If manure is not used, some green-manure crop is turned under to maintain the humus supply. The green-manure crop is usually grown after an early crop of vegetables has been removed, since kale is not planted until late summer or fall. Fertilizer experiments at the Virginia Truck Experiment Station[1] have shown the importance of phosphorus on the sandy-loam soil used for kale in that region. In general the experiments indicate that production can be maintained by the use of commercial fertilizers, lime, and green-manure crops.

Planting.—Kale is grown as a fall, winter, and early spring crop in the South and the seed is planted in late summer and fall. In the North the crop is grown either in the fall or early spring. Seed for the fall crop is planted in July and August depending on the locality, elevation, etc. Spring planting should be done as early as the soil can be prepared.

Seed is sown with a drill and the rows are spaced 18 inches apart for hand cultivation and 24 to 30 inches apart for horse culture. After the plants are well established they are thinned to stand about 6 inches apart. When grown for home use, the plants removed in thinning are usually used as food.

Cultivation and Care.—Clean cultivation is given kale and the general care is about the same as for spinach.

Kale is attacked by the same insects as cabbage, especially by the false cabbage aphis (*Aphis pseudobrassicae* Davis), the true cabbage aphis (*Aphis brassicae* Linn.), the cabbage worm, the cabbage looper, and the harlequin cabbage bug. The same sprays suggested for the control of these insects on cabbage will control them on kale, but for successful kale spraying a specially rigged sprayer should be used. The nozzles should be near the ground and arranged in such a way that two of them spray the same row so that the material strikes the plants from the sides. According to Zimmerly and Smith (1920) the cost of spraying kale with a power machine, covering six rows at a time, was only $2.07 per acre for one application of arsenate of lead. With nicotine sulphate and soap the cost was $3.46 per acre for one application. These figures are for spraying kale in 20-inch rows. The cost was a little less where the rows were farther apart.

Varieties.—The varieties of kale grown in the United States belong to two groups, Scotch and Siberian. The foliage of the former is grayish-green in color and very curled and crumpled while that of the Siberian is of a bluish-green color and curled but not quite as much as the Scotch. Both dwarf and tall forms are grown, but the former is the more popular.

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[1] *Bull.* 9.

The most common varieties are Dwarf Curled Scotch or Norfolk, Early Curled Siberian, Tall Scotch and Dwarf Green Curled.

Harvesting.—For home use the leaves are often picked from the plant, while for market the entire plant is cut off near the ground using a large knife. The discolored and injured leaves are removed and the plants packed for shipping without washing. In the Norfolk, Virginia, region kale is packed in barrels for shipping to the northern markets.

MUSTARD

White mustard (*Brassica Juncea*) is grown for salad and greens to some extent, but has been replaced largely by spinach and kale. This plant is a hardy annual of the Cruciferae family. Seed is sown very early in the spring for spring use and in the fall for a winter crop. The plants go to seed quickly in the spring. The seed is sown thickly in drills 12 to 15 inches apart and the plants thinned as they crowd in the row. The White London is one of the well-known varieties of this species.

On a good sandy-loam soil 50 to 75 pounds of nitrogen, 100 to 150 pounds of phosphoric acid, and 50 to 75 pounds of potash per acre should give good results even without manure, provided the humus supply is maintained by turning under soil-improving crops. Where manure is used an application of 25 to 30 pounds of nitrogen and about 80 pounds of phosphoric acid should be sufficient.

Giant Curled and Ostrich Plume are varieties of *Brassica Japonica* grown to some extent in the South. Both of these produce large curled leaves. The Ostrich Plume, or Giant Ostrich Plume, is the most important variety of mustard in some sections of the South.

Black mustard (*Brassica nigra*) is grown largely for its seed, which is made into the mustard of commerce. This type is grown to a large extent on the adobe soils in Santa Barbara County, Calif.

In the South, mustard is grown to a considerable extent as a trap crop for the harlequin cabbage bug. It is planted near the cabbage or other crop to be protected and on it the bugs collect. Plants and bugs are killed by spraying with pure kerosene or kerosene emulsion early in the morning when the bugs are inactive.

COLLARDS

The collard (*Brassica oleracea* var. *acephala*) is an important green vegetable in Southern gardens and on Southern markets in the winter months. The edible portion is the green rosette of leaves, resembling cabbage leaves prior to heading.

The collard will withstand a greater range of temperature, both heat and cold, than any other vegetable crop grown in the South. Miller

(1934) states that it will withstand 15°F. unless this temperature follows a period of warm weather.

There are two methods of planting the crop. One is to sow the seeds in cold frames or on row beds and to transplant the plants to the garden or field when they reach a height of 6 to 8 inches. The plants are spaced 18 to 24 inches apart in rows with rows 3 to 3½ feet apart. The second method is to sow the seed in a well-prepared permanent row, thinning the plants to the desired spacing. The planting season in the coastal region of Louisiana is from July to November. In most interior regions of the South, planting is done in the spring.

The collard is grown on all kinds of soil but sandy loams and silt loams are considered best. Soil preparation, fertilization, and cultivation recommended for the cabbage crop are satisfactory for collards.

Miller describes the harvesting and the preparation for market as follows:

> There are three methods by which the collard is prepared for market. The first and the one most commonly used in the market-garden areas is to cut the mature head or rosette. The rosette may be pulled together and tied with a string. The second method and the one most extensively used by the market gardeners and truck growers along the Gulf Coast is to cut the plants when they are about one-eighth to one-fourth their normal size and to tie them together into a bunch. This method of bunching lends itself to the use of smaller shipping containers, and the product also gives a better appearance on the market. The third method is to cut the lower large leaves of the plant and tie them into a bunch, weighing from one and a half to two pounds.
>
> The shallot barrel and California lettuce crate are the two containers most commonly used in this state in shipping collards to market. Of the two the lettuce crate is the more desirable.

DANDELION

The wild dandelion is a great favorite for spring greens. For this purpose it is cut from meadows and lawns where it is considered a noxious weed, since it drives out grasses and other plants.

The dandelion has been improved in size and vigor by culture and is grown to a considerable extent as a potherb in Europe and in a small way in the United States. Some of the varieties or strains resemble endive. The cultivated dandelion has been developed from the wild species, *Taraxacum officinalis*, a member of the Compositae, or sunflower family.

Dandelion seed is usually sown in the place where the crop is to mature, although the plants may be started indoors and transplanted to the garden in the spring. The plants should stand 10 to 12 inches apart in the row with the rows 15 to 18 inches apart for hand cultivation. A sandy or light loamy soil is preferred. The crop is usually harvested like spinach. The plants are sometimes blanched by tying the leaves together, or by covering to exclude the light.

Dandelion plants are sometimes forced in hotbeds or in greenhouses for winter and early spring markets.

CHAPTER XVIII

SALAD CROPS

Celery
Lettuce
Endive
Witloof Chicory
Parsley
Chervil
Cress
Corn Salad

Salad plants, in general, thrive best during the cooler parts of the growing season; to be of the highest quality their growth must be fairly rapid and continuous. Celery and lettuce are the only crops in this list that are grown on a large commercial scale and they are found on the market throughout the year.

Salad crops are appreciated now more than ever because of the increase in knowledge of their value in the diet. They are especially valuable for the ash constituents and for their vitamin content, as well as for supplying bulk. These crops generally are eaten without cooking and are the main ones so consumed.

CELERY

Celery is second in importance of the salad crops in value and in popularity, being exceeded only by lettuce. Until comparatively recent times celery was considered a luxury, but it is now a common article in the diet and is available throughout the year.

Statistics of Production.—During the 20-year period, 1918–1937, the commercial acreage of celery more than doubled as is shown in Table XXV.

The figures given in Table XXV do not include all of the celery grown for market in the United States, but only the crops grown in the states showing a considerable acreage, nine states in the early years and 13 states in later periods. In 1937, California was the leading state in acreage with 14,700 acres; Florida second, with 7,500 acres; Michigan third, with 5,100 acres; New York fourth, with 4,700 acres; and New Jersey fifth, with 2,400 acres. These five states produced over 80 per cent of the 40,590 acres grown in the 13 states in 1937. The other important states are Pennsylvania, Ohio, Indiana, Colorado, Idaho, Utah, Oregon, and Washington.

History and Taxonomy.—Celery is a plant of marshy places and according to Sturtevant, its habitat extends from Sweden southward to Algeria, Egypt, Abyssinia, and in Asia even to the Caucasus, Baluchistan, and the mountains of India. It has been found growing wild in Terra del Fuego, in California, and in New Zealand. The wild plant was probably used for medicinal purposes hundreds of years before it was used as food. There is no evidence that it was grown by the ancients as a food plant, but if it was planted at all it was for medicinal purposes. The first mention of its cultivation as a food plant was in 1623 in France. The first cultivated celery differed little from the wild plant.

Celery, *Apium graveolens*, is a biennial plant, although grown as an annual crop. Under some conditions the plant behaves as an annual, developing flowers and seeds during the first year, as mentioned under "premature seeding." Celery belongs to the family Umbelliferae. The flowers are small, white, and are borne in compound umbels among the leaves of the flower stalk, which grows to the height of 2 to 3 feet.

TABLE XXV.—AVERAGE ANNUAL ACREAGE, PRODUCTION, AND FARM VALUE OF CELERY GROWN IN IMPORTANT PRODUCING STATES BY 5-YEAR PERIODS, 1918 TO 1937
(U. S. Dept of Agr. Statistical Bull. 1938.)

Years	Acres	Yield, crates per acre	Production, crates (000 omitted)	Price per crate	Farm value (000 omitted)
1918–1922	15,594	275	4,292	$2.17	$ 9,311
1923–1927	24,012	268	6,441	1.93	12,411
1928–1932	32,620	281	9,168	1.59	14,598
1933–1937	35,086	260	9,124	1.56	14,199

Climatic Requirements.—Celery thrives best when the weather is relatively cool and with a moderate, well-distributed rainfall during the growing season. Of course, the crop can be, and is, grown in relatively dry regions by supplying water artificially. Even in so-called humid regions irrigation is used to advantage. Few crops suffer more than does celery from deficiency of water. Celery requires a relatively long growing season. Celery production is confined largely to regions having either a mild winter climate, as in parts of Florida and California, a relatively cool growing season during summer, or a long growing period in the fall. Some regions, influenced by large bodies of water, such as portions of New York, Michigan, and Ohio, have both a relatively cool growing season in summer and a long growing period in the fall. Other regions, such as the mountain valleys in Colorado and other states, produce celery during the relatively cool summers.

Soil Preferences.—The best soil for celery is a good type of well-drained muck; a large part of the crop produced in New York, Ohio, Michigan, and California is grown on this type. Some of the crop produced in Pennsylvania, Florida, and New Jersey is also grown on muck.

Any good loamy soil will produce a satisfactory crop of celery if the weather and moisture conditions are suitable. A sandy-loam soil, well supplied with humus, is preferred to any other type of mineral soil, although celery can be grown on any rich well-drained soil. A heavy clay should be avoided.

Some authorities believe that celery grown on muck soil is inferior in quality and has poorer keeping properties than that produced on mineral soils. There is no evidence available on which to base a comparison of keeping qualities of celery grown on different kinds of soil. Since most of it put in cold storage is grown on muck soil one would assume that such celery keeps fairly well. In the matter of quality the comparison is based on different varieties. Comparing the same variety grown on muck and on mineral soil at the same time and in the same locality the advantage, the author believes, is in favor of the muck soil. To be of the best quality celery must have a continuous growth and this is more likely to take place on muck than on mineral soils due to the better physical condition and greater water-holding power of the former.

Preparation of the Soil.—Soil for celery should be given the very best preparation through good plowing and thorough pulverizing. The soil should be deeply plowed in order to hold as much moisture as possible in the surface, since celery is not a deep rooted plant and is easily injured by drought.

The time of plowing is determined to some extent by the previous use made of the land. If a cover crop is grown just ahead of the celery the land should be plowed long enough in advance to allow the material turned under to become partially decayed.

In preparation for planting, the surface soil should be well pulverized by harrowing, disking, and rolling or by whatever methods are necessary to make the surface fine. Just before planting the land should be rolled or dragged in order to have an even surface. The use of the roller or heavy drag is especially important on very loose muck soils, since packing is an advantage on such soils.

Manures and Fertilizers.—Celery is a heavy feeder and a poor forager, therefore, large quantities of fertilizers usually are applied. Where mineral soils are used for growing the crop, manure generally is used in large quantities except in regions where the water requirements are met by irrigation. In the vicinity of Sanford, Fla., where subirrigation is practiced, the crop is grown very successfully with commercial fertilizers, and here large applications are given. Results of experiments at the Rhode Island Experiment Station, reported by Crandall (1937), show that stable manure, in both yield and profit, was superior to green manures for celery on a fine, sandy-loam soil. Manure was priced at $10 a cord, or about $5 per ton. In these experiments, two vegetable crops were grown on the manured plots each year, while only one vegetable crop was grown on the green-manure plots each year. Yearly applications of 16 tons of manure to the acre, supplemented with approximately 1000 pounds of a 4–8–6 fertilizer or with 1500 pounds of a 6–8–6, produced larger yields and greater profits than green manures and 1500 pounds of a 6–12–6 or the same quantity of a 6–10–8 fertilizer. Applications of 24 or 32 tons of manure did not produce significant increases in yield over 16 tons of manure. An application of 8 tons of manure increased the yields significantly on the green-manure plots.

Experimental results and experience of growers both indicate that celery is more dependent on manure than are most other vegetable crops. Under most conditions it is advisable to use it on mineral soils for the production of celery if the manure is not too expensive. This is particularly true where irrigation is not used.

Where 15 to 20 tons of manure are used to the acre it is advisable to apply a fertilizer supplying about 75 to 100 pounds of nitrogen, 100 to 125 pounds of phosphoric acid, and 50 to 75 pounds of potash. Without manure, more nitrogen and potash can be used to advantage on most sandy-loam soils and a fertilizer approaching a ratio of 1:1:1 is suggested, with a total application of 125 to 150 pounds of each of the three important elements. Some celery growers use much more than this, but it is doubtful if the crop, grown under ordinary methods, can utilize more than the quantities mentioned. For close-culture celery, heavier applications may be desirable and practicable.

The fertilizers used for growing celery on muck soils usually contain a large proportion of potash. Workers at the Michigan Experiment Station (*Circular* 165) recommend 1200 to 1500 pounds of a 3–12–15 fertilizer for early celery grown on well-drained, nonalkaline, newly cleared muck soil, and 1200 to 1800 pounds of the same on poorly-drained, shallow, or very acid muck. For midseason and late crops, they recommend 500 pounds of 0–8–24 on well-drained, nonalkaline, newly reclaimed, muck and the same quantity of 0–8–24 or 3–9–18 on old muck that is well-drained and nonalkaline. In New York the recommendation for celery grown on new muck is 3000 pounds per acre of a 3–12–18 for close culture (rows 18 to 24 inches apart) and 2000 pounds of 3–12–18 for the crop grown in rows 30 to 40 inches apart. On old muck the New York recommendation is for 2500 pounds of 4–8–12 for close culture and 2000 pounds for celery grown in rows 30 to 40 inches apart.

Under many conditions it is desirable to apply additional nitrogen as side dressing during the growing season as the plants show the need of it. In some cases one application of 20 to 25 pounds of nitrogen is sufficient, while in other cases two or three applications may be desirable. The nitrogen applied as side dressing should be in a readily available form.

Common salt is used at the rate of 500 to 1000 pounds to the acre by some growers in Michigan. They believe that the celery is benefited by the salt, and, while no experimental evidence has been presented, the authorities of the Michigan Experiment Station express the opinion that the yield is increased and the quality of the crop is improved by the use of salt on new, unfertilized muck. The writer questions the value of salt when the celery is fertilized with fertilizer containing sodium and chlorine.

Sowing Seed.—Celery seed is never planted where the crop is to grow to maturity, because of the care necessary to get a stand of good plants. The seeds are small and germinate very slowly and the plants are delicate when small so that special attention is necessary to get them started.

The time of sowing seed is determined largely by the time the crop is desired for use. If the plants are not to be transplanted before being set in the field, 8 to 10 weeks is sufficient in most cases, although in some regions large plants are desired for setting out during hot weather, especially where furrow irrigation is used, in which case a longer period in the seedbed is required. In Florida, where celery is grown in the fall, winter, and early spring, seed sowing begins in July and continues at intervals during the fall and early winter. The chief problem there is to get the plants started during the hot weather of summer. Partial shading of the seedbed helps in bringing the seedlings through the hot weather. It is not desirable to sow seed any earlier than is necessary to get plants large enough for planting at the proper time. When the plants are transplanted once before being set in the field, 10 to 12 weeks time should be allowed.

Soaking the seed, prior to planting, hastens germination and is practiced by some growers, especially for the late crop of celery. A common method is to moisten the seed in a pan or other receptacle and put in a warm place where it is kept for several days or until the sprouts begin to appear. Another method is to place the seed between folds of cloth. The cloths are kept moist. Care must be taken to prevent the seeds from drying out as this would injure their vitality. As soon as the sprouts appear the seeds should be planted because if the sprouts are allowed to grow too long there is danger of breaking them in planting. When ready for planting the seed is spread out in an airy place to dry, but complete drying should not be allowed. Many growers mix the seed with ashes, dust, corn meal, or other substances to take up the moisture and to aid in distributing the seed.

Celery seed may be sown in rows or broadcast; both methods are used. Broadcasting gives a better distribution of plants but sowing in rows gives an advantage in watering, thinning, and weeding. When plants are started in the greenhouse or hotbed the seed is sown broadcast, or in rows about 2 inches apart and covered with pieces of burlap or with about 1/8 inch of soil. Sometimes the burlap is used even when the seed is covered with soil. The burlap prevents washing the seed into piles when watering and also prevents rapid drying of the surface of the soil. As soon as the seedlings appear, the covering should be removed to prevent injury to the plants. When the seed is sown in outdoor beds, broadcasting is sometimes practiced and the beds are covered with burlap. Sowing in rows 12 to 18 inches apart with a seed drill is popular in some sections. By this method the plants can be kept well cultivated with hand cultivators. Thinning can be done more easily when the plants are grown in rows.

When the plants are grown in the greenhouse and are transplanted prior to setting in the field, 2 ounces of seed is sufficient for one acre planted in single rows 3 feet apart. When the seed is sown in outdoor beds, and the plants are taken direct from the seedbed to the field it is advisable to sow 1/4 pound for each acre to be planted.

Care of Plants.—Very close attention to watering is necessary before the seeds germinate and while the plants are small, especially when grown in the greenhouse or hotbed. The surface of the soil should never be allowed to dry out until the plants become well established, but keeping the soil soaked should be avoided. When this method of growing plants is used the weeds should be kept under control and the soil stirred between the rows.

Plants for the very early crop are often transplanted before time for setting in the field. This is done 4 to 5 weeks after the seed is sown. They may be set into flats, or into the soil of the hotbed or greenhouse, spacing the plants 1½ by 1½, or 2 by 2 inches. This transplanting is done as soon as the plants reach sufficient size, 1½ to 2 inches.

For a large portion of the acreage planted, the plants are taken direct from the seedbed to the field, since transplanting is very expensive and is of little advantage except for the very early crop.

Setting the Plants.—Before the plants are taken up for setting in the field, the plant bed should be watered, preferably a few hours in advance of lifting the plants. This is especially desirable with plants that have been transplanted, as the watering will make the soil adhere to the roots. It is desirable to set the plants when the soil is moist and the air rather humid, as there is less wilting of the foliage under these conditions than when the soil and air are dry. When it is necessary to plant in dry soil it is desirable to apply water at the time of setting. Machine planters are equipped to apply water in the small groove made to receive the plant; this is an excellent method as the roots come into direct contact with the moist soil. If plants are set by hand, water may be applied either before or after planting, preferably after, unless the soil is very dry.

In irrigated regions the soil may be irrigated either before or after planting, but when the soil is very dry some wetting before setting the plants is desirable.

Plants generally are set on the level in unirrigated sections, but in some cases they are set below the level of the surface. In irrigated sections the plants sometimes are set on the side of the irrigation furrow.

Trimming both the foliage and the roots is a common practice in some regions, especially where the plants are allowed to get large before being set in the field. The cutting back of the taproot is practiced only when the plants have been allowed to grow in the seedbed until ready for field planting. The object of this pruning is to stimulate the development of lateral roots. There is difference of opinion regarding the desirability of pruning off part of the foliage. It seems probable that it is not necessary, or even desirable, unless the plants are rather large and the root system considerably reduced in taking up the plants. Under conditions favorable for growth of the plants, reducing the leaf area seems to delay development. On the other hand, when the conditions are unfavorable for growth some reduction of the foliage may be an advantage, especially when the plants are large.

Celery plants are set 6 to 8 inches apart in the row, with the rows 18 to 24 inches apart in close culture and 3 to 6 feet in the ordinary method followed by most growers. Plants sometimes are set in double rows 6 inches apart each way with the sets of rows 3 to 5 feet apart. This practice is not so common as it was formerly. The main objection to it is that, since it is impossible to cultivate between rows 6 inches apart, the work must be done by hand. On muck soil in the East, 3, 3½, and 4 feet between the rows are the most common distances. For blanching with boards or paper 3 feet apart is sufficient, but where soil is used for blanching the distance should be greater.

Celery plants are set by hand and by machine. Machine planters do a very satisfactory job on level or nearly level surface, provided the soil surface is smooth. The plants must be set at a fairly definite depth, deep enough to prevent drying of the roots but not so deep as to cover the growing point. Plants that have been transplanted prior to setting in the field usually are taken up with a block of soil; such plants can be set by hand in a shallow furrow made with a small hand plow. Nontransplanted plants, when set by hand, are set in openings made with a small dibble or with the forefinger.

In planting celery, it is very important to have straight rows equal distances apart for convenience in spraying and blanching. The use of a line or a marker is advisable. A good method is to use a sled marker with a small strip of iron on the runners. This is especially good when the soil is dry as the runners push the dry soil aside and the small strip of iron makes a groove into which the plants are set. This small groove is especially desirable when the soil must be moistened before or after setting the plants, since only a small quantity of water is necessary to moisten the soil in the groove.

Cultivation.—Good clean cultivation throughout the growing season is important, since weeds are troublesome on most soils used for celery growing. The celery plant grows slowly and is soon injured by weeds. Celery responded more to cultivation for the purpose of maintaining a soil mulch than any of the other crops grown in the cultivation experiment at Ithaca, N. Y. Celery roots do not have so much spread as most other vegetable-crop plants and it is thought that because of this less moisture is intercepted by celery roots than by roots of cabbage, for example. Figures 20 and 21 show the distribution of roots of full-grown celery plants in a sandy-loam soil at Ithaca, N. Y.

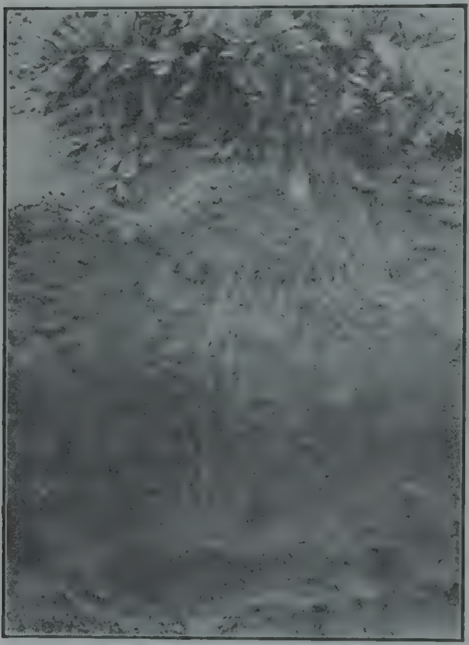

FIG. 20.—Roots of celery growing down into the soil. Note limited distribution of roots. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

When the plants are small, hand cultivators or small tractor cultivators are used near the rows, and larger implements for cultivating the centers. When weeds are troublesome, knife or blade attachments generally are used, although small disks are employed to some extent when the plants are small. When the disks are used the row is straddled with a two-wheel cultivator, one set of disks running on each side of the row. These disks throw the soil away from the plants and leave them on a little ridge, which is leveled down in hand weeding. The disks are employed only in preparation for hand weeding.

In all cultivation the surface soil should be left as level as possible, therefore, it is desirable to use small-toothed cultivators. Shallow cultivation is desirable at all times, especially near the plants, as many of the roots grow near the surface and within 6 to 12 inches of the row.

Blanching.—The blanching of celery results in the loss of the green coloring matter and the strong flavor. Blanching is accomplished by excluding the light from the leaf stalks while the plants are still growing.

Several methods are employed including the use of boards, paper, and soil. Paper has taken the place of boards in many regions because it requires much less labor to place in position and because the first cost is less than with boards. Paper and boards are used almost exclusively for blanching celery in hot weather and are used throughout the season in some regions where it is not necessary to use soil for protection against freezing injury. Celery banked with soil is likely to rot in hot weather.

Boards used for blanching celery are usually 1 inch thick, 10 to 12 inches wide, and 14 to 16 feet long. A good grade of hemlock is considered satisfactory although other kinds of woods are used. A lightweight durable wood is desired. The boards are first laid flat along both sides of the row; then two men, working together, at opposite ends of the board take hold of the edge nearest the plants and raise it so that it catches up the leaves. When the board is in a vertical position it is held by one hand while with the other the board on the opposite side of the row is raised. They are held in place by wires bent in the form of double hooks 6 to 8 inches long. These wires are placed over the upper edges of the boards at the ends and sometimes at one or two places in between. Short pieces of laths are sometimes tacked across the tops to hold the boards in place. After the boards are in place, a little soil is thrown along the lower edge to close any openings that may be present due to unevenness of the soil, Fig. 22.

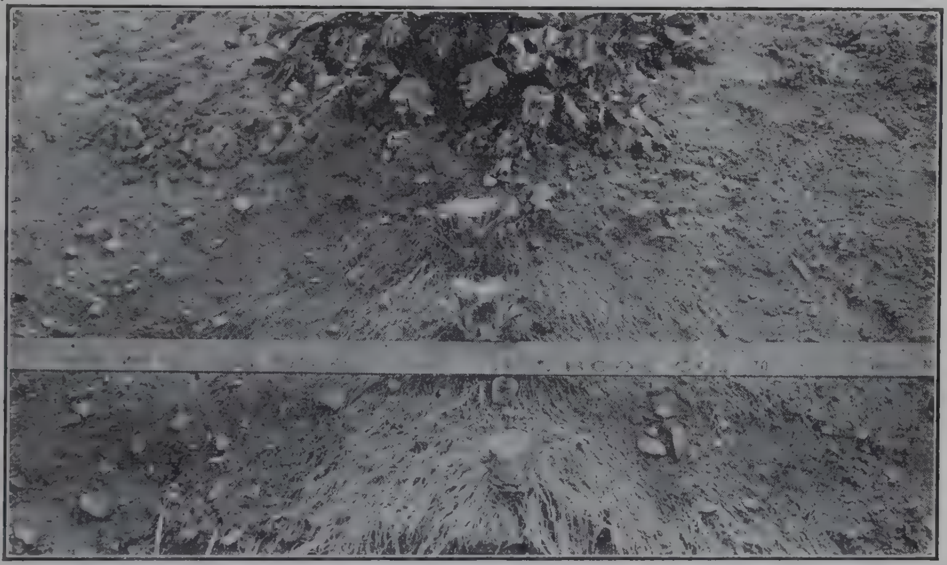

Fig. 21.—Roots of celery plants uncovered by washing off the surface soil to the depth of 2 inches. Note the large number of coarse roots, confined to a limited zone. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Two types of paper are used for blanching celery, ordinary building paper and a paper similar to heavy roofing paper but without the objectionable tar. The latter type is much more durable than the former and if given the proper care will last for several years. The advantage of the paper over boards lies in the fact that it is much lighter in weight and therefore does not require so much labor to apply.

The paper is cut into strips 10 to 12 inches wide and is bought in rolls. In applying the paper to the celery, two rolls are used at a time, one on each side of the row. It is unrolled and set on edge against the celery plants and is held in place by wires bent in the shape of an inverted U, with each leg about 18 inches long. The wires are placed over the row with one leg on each side and the ends are pushed into the soil to the depth of 6 or 8 inches.

Banking with soil (Fig. 23) is the most economical method. The soil is worked up to the plants gradually in order to avoid getting it into the center of the plant. The banking is usually done by means of a celery hiller, Fig. 22, which pushes the soil against the plants. The wings of the hiller are adjustable so that the soil can be pushed to any desired height. As cold weather approaches, the soil is usually worked up to the tops of the plants.

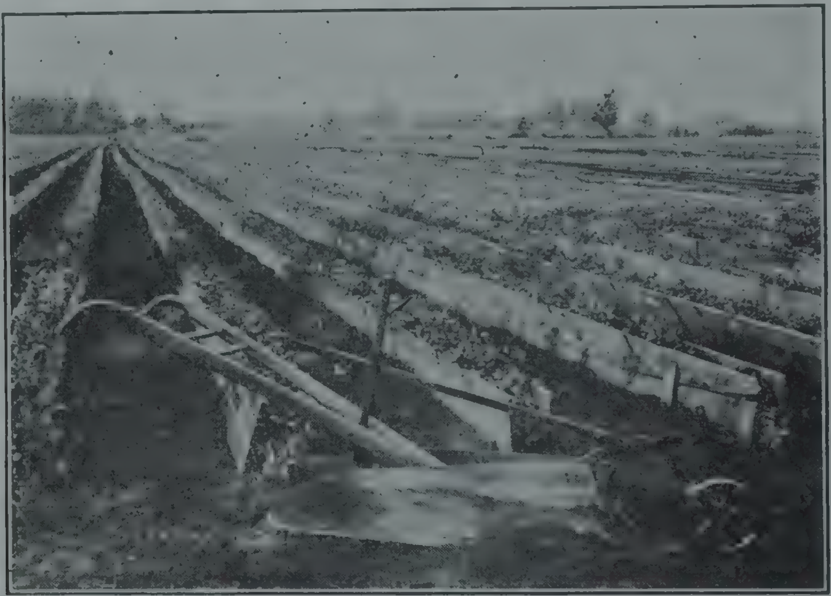

FIG. 22.—A field of celery on muck soil showing use of boards in blanching. In foreground a type of celery hiller used in banking celery with soil. (*Courtesy of U. S. Dept. Agr.*)

The length of time required for blanching depends on the variety and the growing conditions. The so-called self-blanching varieties, such as Golden Self Blanching, blanch in much less time than the green varieties such as Giant Pascal, Winter Queen, and Emperor.

When celery is growing rapidly it will blanch in less time than when the growth is slow. In summer, 10 days to 2 or 3 weeks are usually required while in the fall a longer time is needed, unless the crop is to be stored, in which case it is not completely blanched when harvested.

Green varieties require several weeks to blanch properly but since these are grown for late fall and winter use part of the process is accomplished in storage. As soon as the crop is properly blanched it should be harvested, because if left too long it loses flavor.

Blanching with Ethylene Gas.—During the past few years considerable interest has been aroused in the use of ethylene gas for blanching celery. This method was worked out by Dr. R. B. Harvey, and, while it has been used successfully, it is not employed commercially to any great extent. Harvey (1925) states that self-blanching varieties can be blanched in 6 days, and the dark green varieties in 12 to 14 days by the use of ethylene. A concentration of ethylene, varying between one part in one thousand and one part in ten thousand of air, is suggested by Harvey. For best results the atmosphere needs to be fairly humid and the temperature between 50° and 80°F. Harvey recommends a temperature of 65°F. The gas can be used in a tight storage room, in a refrigerator car, or in any other enclosed space where there is little leakage of air. When used in a room that is nearly airtight, one treatment is sufficient for the so-called self-blanching varieties and two treatments for the green varieties.

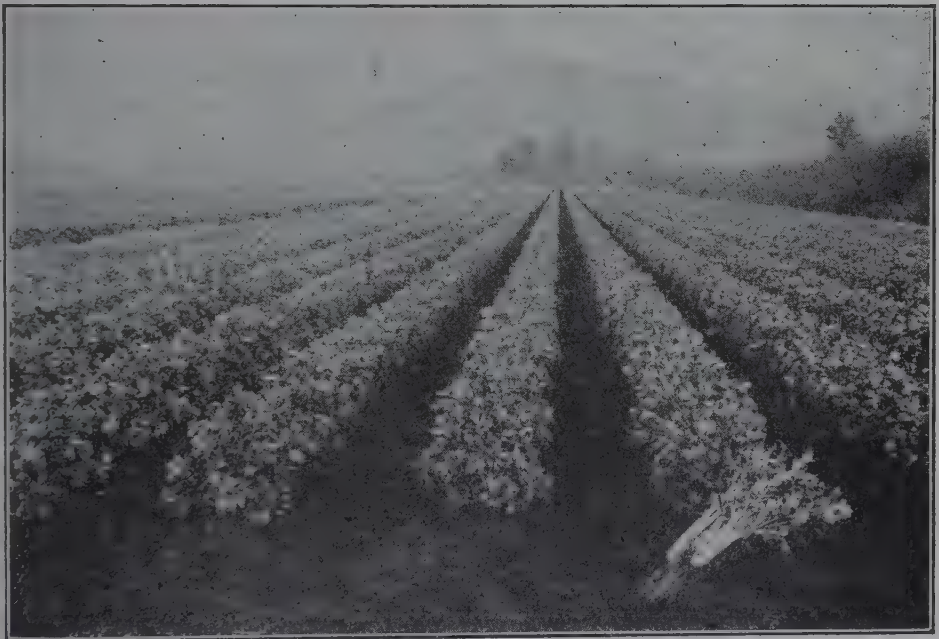

Fig. 23.—A field of celery grown on muck soil, blanched with soil. (*Courtesy of U. S. Dept. Agr.*)

Harvey states that the quality, texture, flavor, and color of celery blanched with ethylene is equal, if not superior, to that blanched by other methods and the keeping qualities are not impaired by the treatment. It is supposed that the gas hastens the ripening process by speeding up enzymatic action.

Not all experimenters have been so successful as has Dr. Harvey in the use of ethylene and for this reason the method is not one to be recommended unqualifiedly. One objection to it is that the foliage, as well as the stems, is blanched and the yellowed foliage is not so attractive as the green leaves.

Varieties.—Distinct varieties are not so numerous nor so clearly separable from each other as is the case with most vegetables. Catalogues from 60 leading seedsmen of the United States list only 65 varietal names and it is practically certain that there are not over 20 American varieties that are distinct enough to justify separate naming.

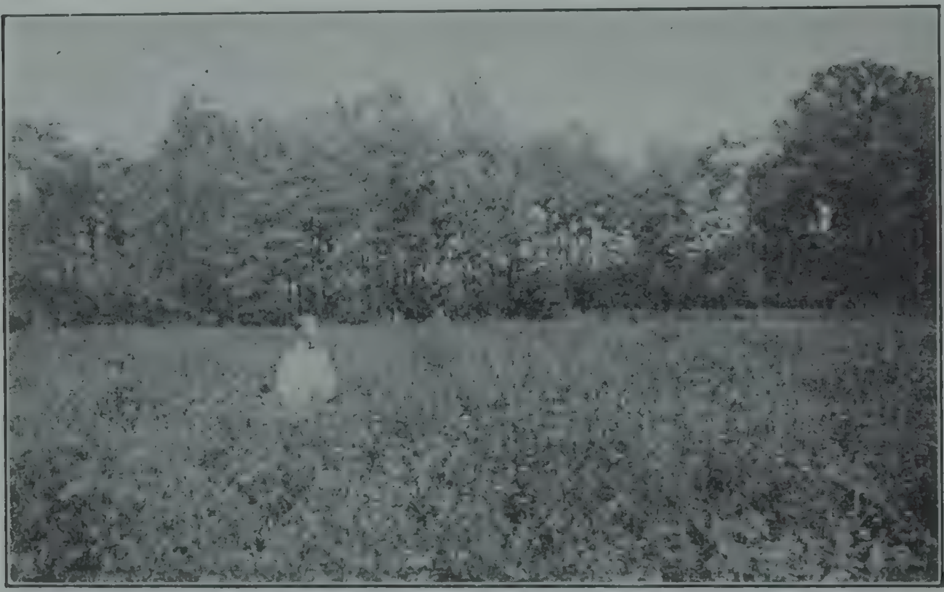

Fig. 24.—Premature seeding of late celery at Williamson, N. Y., in 1924. Over 60 per cent of these plants produced seed stalks and were worthless for market. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Self-blanching varieties are used for a large part of the acreage of celery grown, but some of the green varieties are increasing in importance because of their high edible quality. Of the self-blanching varieties the most important are Dwarf Golden Self Blanching, Tall Golden Self Blanching, Golden Plume or Wonderful or Early Fortune, and Golden No. 14. The most important varieties of green celery are Giant Pascal, Utah, and Salt Lake, the latter two being of the Giant Pascal type, but not so dark green in color. Emperor and Columbia are other varieties of green color and of high quality, but are not good commercial varieties because of brittleness and the small number of leafstalks.

For high quality, the Pascal type is the one to grow. It is vigorous and has thick, rounded petioles of excellent quality. It is difficult to blanch and for this reason is not grown to any large extent except in a few localities, but is increasing in popularity.

Premature Seeding of Celery.—Celery growers in various regions, especially in the Northern states, frequently suffer serious financial losses due to the plants shooting to seed before they reach marketable size. Figure 24 shows a field of celery grown on muck soil at Williamson, N. Y., in 1924. In that year celery growers in New York lost hundreds of thousands of dollars due to this premature seeding, and similar losses were incurred in other states.

TABLE XXVI.—EFFECT OF CHECKING GROWTH BY DRYING, ON SEEDSTALK DEVELOPMENT

Date of sowing seed	Treatment	Total number of plants	Number and per cent of seed stalks in the given number of days from field planting						
			51 days		75 days		112 days		Number of years
			Number	Per cent	Number	Per cent	Number	Per cent	
Dec. 10.........	Check	349	222	63.6	305	87.4	316	90.5	3
Dec. 10.........	Dry	287	89	31.0	223	77.7	246	85.7	3
Jan. 10.........	Check	651	102	15.6	336	51.6	416	63.9	4
Jan. 10.........	Dry	556	39	7.0	149	26.7	235	42.2	4
Feb. 10.........	Check	646	5	0.60	91	11.5	192	25.1	4
Feb. 10.........	Dry	551	1	0.18	10	1.8	93	16.8	4
Feb. 25.........	Check	387	0	0.00	2	0.51	16	4.13	3
Feb. 25.........	Dry	200	0	0.00	0	0.00	6	3.00	3

Celery growers and others have attributed premature seeding to various factors, such as poor seed, especially seed lacking in vitality; early sowing of the seed; check in growth due to freezing, to drouth, to crowding, to disease, and other things; and to exposure of the plants to relatively low temperature, but not freezing, for a considerable period. Results of experiments in Montana, as reported by Starring (1924), and in New York, reported by Thompson (1929), show that exposure of the plants to relatively low temperature (40° to 50°F.) is the main factor involved in premature seeding. In the experiments carried on at Ithaca, N. Y., checking growth of the plants by freezing, by allowing them to become crowded in the transplanting flats, and by allowing the soil to get dry delayed seedstalk development and resulted in a lower percentage of seeders. The experiments on the effect of checking growth by drying were carried on for 4 years. The method used was to withhold water from some lots of plants for 10 days to 2 weeks before they were set in the field. The soil was allowed to become dry enough to permit the plants to wilt. At the time of planting these plants were yellowish green in color, and considerably checked in growth as compared to the check plants, which were kept well watered. The data from this series of experiments are given in Table XXVI.

In the 4 years, during which these experiments were carried on, there was not a single instance in which drying hastened seeding or increased the percentage of seeders. Starring obtained similar results.

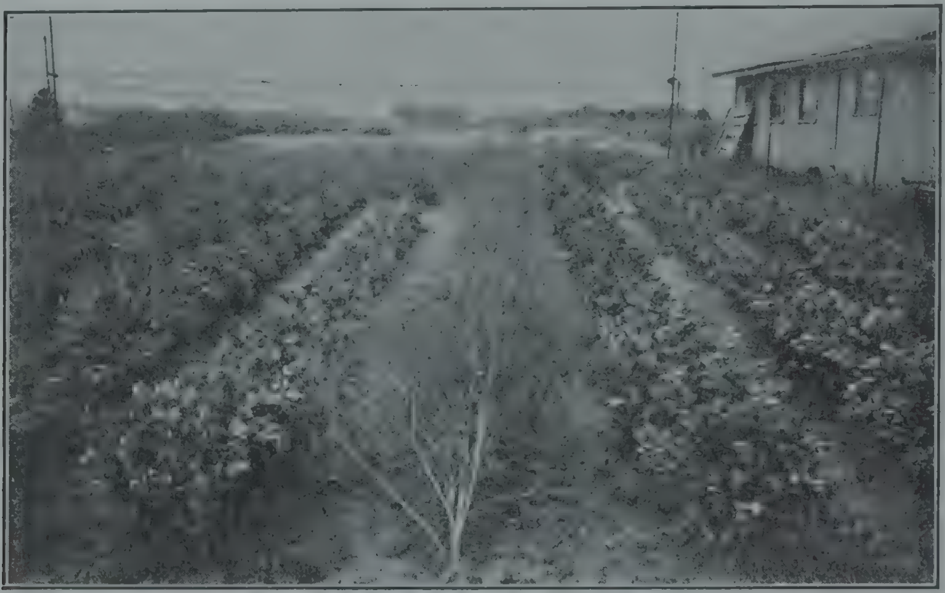

Fig. 25.—Celery plants showing effects of relatively low temperature on premature seeding. Plants in center row grown in cold frame for 35 days; plants in rows on both sides grown in greenhouse (60° to 70°F.) until set in field. All plants of same strain and started at the same time. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Exposing celery plants to relatively low temperatures (averaging 40° to 50°F.) for periods of from 10 to 30 days results in premature seeding when the plants are grown subsequently under conditions favorable for growth. Thompson reported results of experiments carried on for 5 years in which the plants that were subjected for 15 days or longer to temperature averaging 45° to 50°F., always produced some seedstalks in the field before the plants were half grown. Similar plants kept in the greenhouse at temperatures above 60°F. never produced any seedstalks. Figure 25 shows plants started February 10 and set in the field the first of May. All of the plants shown in this picture had exactly the same treatment throughout their growth except for 35 days prior to setting them in the field. The plants showing seed stalks were kept in the cold frame for 35 days before being planted, while the others were kept in the greenhouse until planting time. The greenhouse temperature averaged above 60° and the cold frame averaged between 45° and 50°F. The data on the effects of 30 days' exposure to relatively low temperature on subsequent seeding are given in Table XXVII.

TABLE XXVII.—EFFECT OF 30 DAYS EXPOSURE TO RELATIVELY LOW TEMPERATURE, ON SEEDSTALK DEVELOPMENT IN CELERY STARTED IN FEBRUARY

Year	Check			In cold frame 30 days		
	Total number of plants	Number of seed stalks	Per cent of seed stalks	Total number of plants	Number of seed stalks	Per cent of seed stalks
1924	288	0	0.0	288	146	50.7
1925	518	79	15.2	505	279	55.2
1926	421	153	36.3	438	372	84.9
1927	480	0	0.0	480	142	29.6
1928	900	0	0.0	900	571	63.44
Total.......	2,607	232	....	2,611	1,510	
Average.....	.....	...	8.9	.....	.....	57.83

In 1924, 1927, and 1928 not a single plant from the check treatment went to seed, while in 1925 and 1926 some of them did produce seedstalks. Even the cold-frame plants show some differences. The variation in the check treatments is due mainly to difference in temperature in the greenhouse in which the plants were grown. In 1924, 1927, and 1928, the temperature in the greenhouse averaged 65.2°, 71°, and 67°F. respectively, while in 1926 the temperature averaged 54.5°F. Other experiments carried on wholly in the greenhouse indicate that plants grown for 2 to 3 months under temperatures averaging between 50° and 55°F. go to seed. The variations in the 30-day cold-frame plants probably are due to differences in temperature in the greenhouse and in the cold frame, and to growing conditions in the field.

Experiments carried on for 3 years show that exposure to relatively low temperature for 15 and 20 days resulted in considerable seeding every year, and 10 days exposure resulted in 8 per cent seeders 1 year.

The evidence clearly points to the danger of growing celery plants for 2 or 3 months in a cool greenhouse, and to subjecting them to low temperature (40° to 50°F.) in the cold frame for 2 weeks. The practice of "hardening off" plants in the cold frame is a dangerous one and is not necessary. Hardening can be accomplished by withholding water. The earlier the plants are started, the more likely they are to go to seed the first season, especially when they are grown in what is considered a cool greenhouse. Late celery, from plants grown in an outdoor seedbed, is likely to go to seed if started too early, and for this reason, seed sowing should be delayed as long as feasible.

Varieties and strains differ materially with reference to premature seeding. In general, the earlier and more rank growing strains are more likely to shoot to seed than are the slower growing, later strains and varieties. For example, the so-called tall strain of Golden Self Blanching produced twice as many seedstalks as the dwarf strain during the four years these were compared. The Golden Plume produced less seedstalks than either of the other strains of Golden Self Blanching. However, the conditions under which the plants are grown, especially during the early stage of their growth, determine whether or not variety and strain differences appear. In other words, the environment seems to control the hereditary factor or factors for annual flowering and seeding.

Pithiness.—Pithiness or "hollow stalk" has been ascribed to check in growth, to too rapid growth, and to poor seed, especially to seed produced on pithy plants. Sandsten and White (1902) and Austin and White (1904) presented evidence to show that pithiness is an inherited character. Emsweller (1932) stated that there are two types of pithiness: one in which the entire plant is pithy even when very young and the other in which the outer petioles become pithy when the plant approaches maturity. Emsweller's evidence indicates that the former type is inherited and he states that it is dependent on a single dominant gene. Since the solid-petiole condition is recessive it is a simple matter to establish nonpithy strains. By removing pithy plants from the celery seed field, the inherited type of pithiness could be eliminated in a short time.

Diseases.—Celery is susceptible to injury by several diseases including late blight or septoria blight, early blight, bacterial blight, Phoma root rot, Fusarium yellows, pink rot, blackheart, mosaic, root knot, cracked stem. Some of these are widespread and cause serious losses. Others cause heavy losses in certain localities under some conditions.

LATE BLIGHT.—This disease is caused by *Septoria apii* and is very widespread, being found in all countries where celery is grown. The organism attacks only celery and celeriac. The disease is first observed as small, brown spots on the leaves, but as it develops the spots coalesce and the entire leaf may become dry. Lesions on the stems are somewhat similar to those on the leaves, except that they are more elongated. One characteristic of this disease is the development of small, black, fruiting bodies protruding from the brown spot. The spores are discharged during rains or heavy dews and may be spread by running or splashing water, wind, insects, men, and tools. In California irrigation water is important in the dissemination of the spores. The best temperature for the organism is between 60° and 70°F., therefore, this disease develops fastest in the cooler portion of the growing season.

Treatment of new seed, recommended by some authorities, is soaking the seed in hot water for 25 minutes at 118°–120°F., or in formaldehyde solution (1 to 240) for 30 minutes, or in mercuric-chloride solution for 20 minutes following a half-hour soak in lukewarm water to soften the fungus. The mercuric-chloride treatment is thought to be the most effective, but it should be followed by thorough rinsing in running water or several changes of fresh water, and even then considerable injury to the seed may result so that a small-scale test is advised. Seed that is more than two years old needs no treatment.

Spraying with Bordeaux mixture (5–5–50 or 4–6–50) or dusting with 20–80 copper lime dust should begin in the seedbed and be continued at weekly intervals until the plants are set out. Spraying or dusting should begin in the field as soon as the plants become well established and continued throughout the season at intervals of a week or ten days, or as often as is necessary to keep the foliage well covered with the fungicide.

Early Blight.—The fungus causing this disease is *Cercospora apii* Fres. The name, early blight, is somewhat misleading since in some regions it makes its appearance later than Septoria blight and bacterial blight. In Florida, according to Foster and Weber (1924), the disease appears in the seedbed in October and is carried to the fields on the plants. When cool weather arrives the spread of the disease is checked, but as the weather gets warm in the spring it becomes destructive. The disease attacks leaves in all stages of growth, but is most prevalent on the older leaves. It appears first on the leaves as small circular, yellowish-brown spots. These enlarge rapidly under favorable conditions and in a few days they have a light brown central area, gradually turning to dark brown, surrounded by a band of yellow.

Control measures for this disease are the same as for the late blight.

Bacterial Blight (*Bacterium apii* Jagger).—This disease is generally destructive in New York and is present in Michigan, Indiana, and Minnesota. Celery is the only host for this disease, so far as is known. The spots can be distinguished from those caused by late blight by the absence of pycnidia and from those due to early blight by not having the ashen-gray fruiting mold. This disease is confined almost entirely to the leaves. It lives over winter on refuse celery left in the field or elsewhere, and is disseminated by rain, by insects, and by other means.

The control measures are the same as for late blight. Cultivation should be given after, rather than before, applying the fungicide so that the plants are not infected from spores turned up by the cultivator.

Phoma Root Rot.—This disease is caused by *Phoma apiicola* Klebahn. The first symptoms of disease on the plants is a wilting and dropping of the leaves and a generally unhealthy appearance of the plant. The disease starts at the base of the stems and the tissues turn bluish green when first invaded by the fungus, but gradually turn dark brown or black. It thrives best in relatively cool temperatures (60° to 70°F.).

No satisfactory control measures have been devised for this disease. Crop rotation, burning refuse, guarding against seedbed infection, and destruction of infected seedlings are recommended. Keeping the soil of the seedbed relatively dry aids in controlling the disease on the seedlings.

FUSARIUM YELLOWS.—The causal organism of this disease is a species of Fusarium. Nelson, Coons, and Cochran (1937) state that there are two forms of the pathogen, I and II, and they give the name *Fusarium apii* n. sp. for form I and *F. apii* var. *Pallidum* n. var. for form II. This disease is fairly widespread and is very destructive in some of the important commercial areas as in Michigan, Ohio, New York, and California. Plants attacked by the disease are stunted and yellowish, and the tissues are brittle and bitter in taste. Longitudinal sections of the stem at the crown show the vascular tissue yellow or red in color. The fungus lives in the soil and accumulates as celery is grown year after year on the same land. The optimum temperature for the growth of the pathogen is considerably higher than that for the best growth of celery.

Growing of yellows-resistant strains or varieties is the most satisfactory way of preventing losses from this disease. Michigan Golden and Florida Golden are highly resistant; Paris Golden, Golden Plume, and Early Fortune are moderately resistant; Golden Self Blanching, Golden Detroit, Golden Phenomenal, and Golden No. 14 are very susceptible. Most of the green varieties are either moderately resistant or highly resistant.

PINK ROT.—This disease, caused by *Sclerotinia libertiana* Lib., is important both in the field and in storage. It may attack the plants when small, and the disease is then known as damping-off. When the plants are older the fungus produces a watery soft rot at the base of the stem, and when nearly mature infection takes place about small growth cracks or insect injury on the stems. Often the disease is not very destructive until the crop is in storage, then the tissues take on a pink color, and change to gray or brown. The organism attacks lettuce, carrots, and other root crops.

Thorough spraying, as suggested for late blight, and careful handling of the celery at harvest time are the control measures recommended. In storage the temperature should be kept below freezing and the air fairly dry.

BLACKHEART.—This disease is not caused by any organism, so far as is known, but is known as a physiological disease. It shows first s a slight tipburn on the younger leaves and quickly spreads to most, r all of the young foliage, causing a browning of the tissues. This continues down the petiole, results in shrinkage, and finally kills it. In severe cases the entire heart is killed and blackened. The disease occurs only during hot weather and is most severe when plenty of moisture is available. Foster and Weber (1924) published results of field studies in Florida that indicate that excessive soil moisture caused the development on blackheart. Results of greenhouse experiments conducted by Webb (1938) at Ithaca, N. Y., are in line with those of Foster and Weber. It seems apparent that the development of blackheart is in some way connected with an unbalanced water supply.

MOSAIC.—Celery, like most other plants, has a disease known as mosaic. The cause is unknown. Plants that have mosaic stand stiffly erect, and the tops have a bushy appearance. It is probable that the disease is transmitted by aphids and other insects. Mosaic generally is not serious enough to necessitate remedial measures. Control of the insects and development and use of resistant varieties are the measures that would be feasible. Some varieties are more resistant than others.

ROOT KNOT.—This disease is caused by a nematode, *Heterodea radicicola*, that attacks a large number of plants. The disease is not troublesome in the North, because the organism cannot withstand the winter cold. In the South, however, root knot is a serious disease of many crops, and, under some conditions in Florida, celery is considerably injured.

The most important control measure for this disease in Florida is treatment of the seedbed, since seed sowing is done at a time of the year when the nematodes are most active. Foster and Weber (1924) suggest treating the soil of the bed with sodium cyanide and ammonium sulphate, as one of the best means of destroying the nematodes.

> After the land is plowed distribute over the soil 800 pounds of sodium cyanide, dissolved in water, at the rate of 800 pounds to the acre. The soil is then irrigated to wash the material into the soil. Just before the land is completely saturated, ammonium sulphate is applied at the rate of 1,200 pounds to the acre, and this is allowed to wash down until the soil is thoroughly saturated.

These two compounds react to liberate hydrocyanic acid gas which kills the nematodes and all insects, and all other animal life in the soil. The soil is left rich in nitrogen. Foster and Weber suggest that calcium cyanide may be substituted for the sodium cyanide and ammonium sulphate. About 1,200 pounds to the acre are applied as dust in the bottom of the furrow as the land is plowed. It is not necessary to apply ammonium sulphate. This treatment is cheaper than the other.

Steam sterilization can be used for the seedbed where steam is available.

Cracked Stem.—This disease is one of the so-called deficiency diseases resulting from a deficiency of boron. The first symptom of the trouble is a brownish mottling of the leaf, usually appearing first on the margins of the younger leaves. This mottling is accompanied by a brittleness of the petiole and by the appearance of brown stripes in the epidermis over the vascular bundles (Fig. 25*a*). Transverse lesions finally appear over the vascular bundles and the epidermis and adjoining tissue curl outward. The exposed tissue becomes dark brown in color.

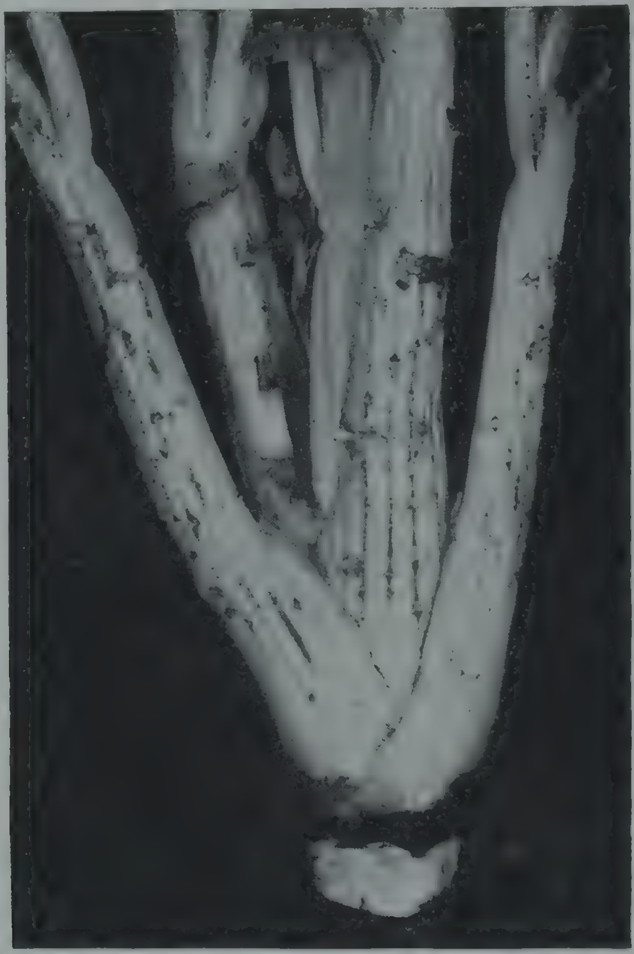

Fig. 25*a*.—Cracked stem of celery, a symptom of boron deficiency. (*Courtesy A. G Newhall. Cornell Univ. Agr. Exp. Sta.*)

Experimental results, reported by Purvis and Ruprecht (1937), indicate that cracking can be controlled by the application of borax. They recommend 10 pounds of commercial borax to the acre applied to the soil near the base of the plants about two weeks after they are set in the field. They state that the simplest and best way to apply the borax is in solution, with a spraying machine. The disks are removed from the nozzles, which are adjusted so that a stream of solution is sprayed close to the plants on both sides of the row. Satisfactory results have been obtained by applying borax in the dry form in New York and in other states. It may be mixed with the fertilizer and applied as is done to control browning of the cauliflower head.

Insects.—Celery is not seriously injured by many insects and it is seldom that any of them cause serious losses. However, under some conditions, the tarnished plant bug and the carrot rust fly cause considerable injury. During dry seasons the tarnished plant bug has caused severe injury in some sections of New York. The celery looper and the larva of the black swallowtail butterfly attack celery, but are seldom very injurious.

CARROT RUST FLY.—This insect is an imported one, being first noticed as injurious to carrots in Canada in 1885. Since that time it has spread through the northern part of the United States.

The maggots eat off the roots of celery and burrow into carrots and parsnips. The leaves of young celery plants turn yellow and the stems below ground become covered with rusty patches.

TARNISHED PLANT BUG.—This is a sucking insect that feeds on a large number of plants. The injury to celery is caused by punctures made by the sharp bristles of the beak, and perhaps by injecting poisonous substances into the tissue. The punctures are made at the joints and cause a blackening of the tissue. The trouble is known by celery growers as black joint.

The adult is a brownish bug, mottled with reddish and yellowish-brown spots, about ¼ inch long or slightly less. The insect hibernates as an adult in the leaves and other rubbish. They emerge in the spring and the female lays eggs in early spring.

Results of experiments in New York indicate that injury can be reduced materially by dusting with superfine sulphur and hydrated lime. The dust should be made of equal parts of sulphur (300 mesh) and of hydrated lime. Dusting should begin as soon as the bugs begin to appear in the field and should be repeated at weekly intervals until harvest or as long as the bugs are present in considerable numbers.

Harvesting.—Celery may be harvested as soon as it attains the proper size and is well blanched. Early celery is often harvested before the plants are full grown, in order to take advantage of a high price. If the crop is to be marketed immediately after harvest, the stalks should be well blanched, but if it is to be put in storage complete blanching is not desired. During hot weather the celery should be taken from the field as soon as possible after it is removed from the row as exposure to sun and wind causes the plants to wilt.

In harvesting, the plants are cut off below the surface of the soil, leaving a portion of the roots attached. This may be done with a sharp knife or spade, but where the crop is grown on a large scale special implements are used. A hand cutter similar to the one shown in Fig. 26 is servicable and is used to a considerable extent. The bean harvester is used to some extent in the celery regions of New York. Various other types are used, many of them being homemade affairs, Fig. 27. With the bean harvester and similar implements two horses are used, one on each side of the row being cut. The cutting bar runs under the row, and is adjustable so that the plant may be cut at any desired depth.

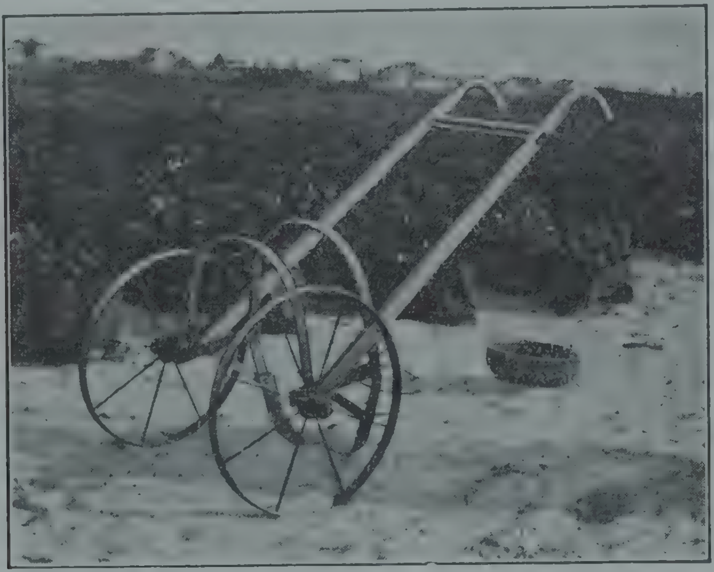

Fig. 26.—A small celery harvester for cutting celery by hand. (*Courtesy of U. S. Dept. Agr.*)

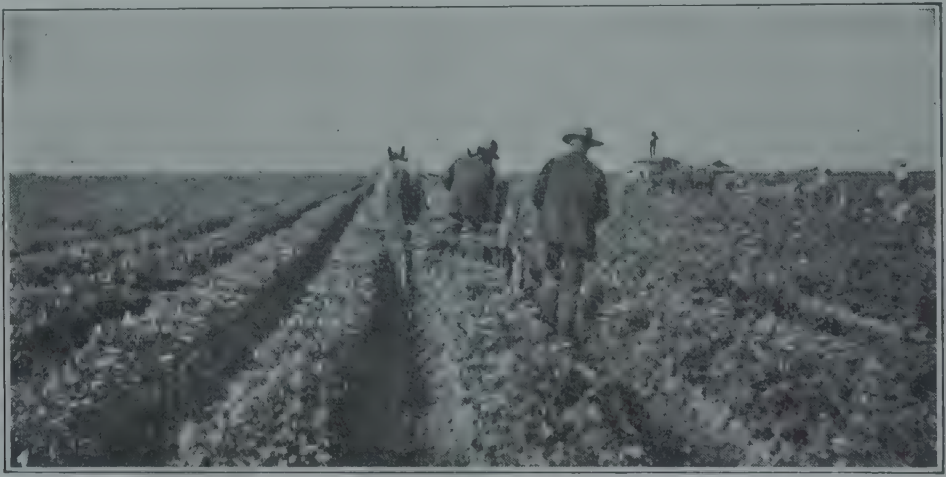

Fig. 27.—A field of celery banked with soil and showing a horse-drawn harvester in operation. (*Courtesy of U. S. Dept. Agr.*)

If the celery is to be shipped without being washed it is usually stripped in the field and packed without any further preparation. The filled crates are hauled direct to the loading station, to market, or to the storage house. When it is to be washed and bunched it is hauled to the washhouse, where it is stripped, washed, and put up in bunches and tied.

Washing.—Celery is usually washed before it reaches the retail store. The washing may be done on the farm, in central packing houses in the producing regions, or in washhouses in the consuming centers. Until very recently most of the celery shipped considerable distances to market was shipped without washing, but in recent years there has been a marked increase in the quantity of celery that is washed before being sent to market. A common method of washing employed in some regions is spraying with water under pressure as the stalks move along on an endless belt. By another method the celery is placed in a tank of water and stirred around to remove the loose soil and then transferred to another tank for rinsing.

When celery is washed before shipping, it is important that it be kept at relatively low temperatures to prevent decay. Moisture is favorable for the development of rots when the temperature is high. After washing the celery should be placed under refrigeration unless it is to be marketed immediately.

Precooling.—The importance of rapid cooling of celery soon after it is harvested is well known and various methods have been used for precooling. Ramsey and Markell (1917) showed that precooled celery reached the market in better condition than did the non-precooled product. With the basketbunker type of refrigerator car iced in advance and properly loaded, the load can be cooled rapidly.

Precooling of celery by means of cold water is practiced at Sanford and Oviedo, Fla. Two methods are employed at Sanford. By one, the celery is packed in the field and is brought to the precooling plant where the crates are immersed in water for about 5 minutes to remove the dirt. After this the packed crates are sprayed and are then put in the precooling tanks where they are kept for about 30 minutes. While the celery is in the precooling room, water at a temperature of 33°F. is sprayed over it. From the precooling room the crates of celery are taken out and passed down a chute to refrigerator cars. By the second method the celery is brought to the precooling plant in wire containers. The stalks are taken out and placed on conveyors which pass through a spraying box where water under pressure sprays the celery, removing all of the dirt. The celery is then sorted into different sizes and packed into crates. The packed crates are then conveyed to the precooling tanks and there they are handled as described for the other method.

The precooled celery is wet when loaded into refrigerator cars and it is claimed that this is an advantage provided the temperature is kept down. When the celery is precooled as described the cars do not have to be re-iced in transit from Sanford to the large eastern markets.

Grading.—Celery grown in some sections of the country is not graded so well as it should be. In many regions most growers make no separation into grades, while in other regions the stalks are graded into two grades, based mainly on size. The United States Bureau of Agricultural Economics suggests two grades for rough celery, U. S. No. 1 and U. S. No. 2. The specifications are changed from time to time and hence are not given here.

In New York the law requires a statement of the number of stalks per crate. The number must be stamped on the crate or on a tag attached to the crate.

Washed celery is graded into two or more grades, the number depending, to some extent, on the demands of the market and on the condition of the product. After celery has been in storage for a considerable period and decay has developed, three grades are often made; the best grade including large stalks with good foliage. The second grade consists of small stalks or those that require considerable stripping to remove the diseased leaves; the third grade consists of the hearts. When practically all of the foliage has decayed and stalks are stripped down to the heart the commercial term "hearts" is applied to this grade.

The Bureau of Agricultural Economics has issued tentative grades for washed celery also. Growers putting up washed celery for shipment would do well to study the specifications.

Packing.—Celery which is shipped "in the rough" is packed in crates in the field without any preparation except to strip off the damaged and discolored leaves. The crate is laid on its side and the celery is placed in it in layers, being packed fairly tightly so that when the crate is full there is no shifting of the product. The celery should not be packed so tightly that air cannot circulate through it.

When celery is prepared for retail trade, it is nearly always washed and in many cases is put up in bunches of from 2 or 3 to 12 stalks per bunch. The bunches sometimes are wrapped with paper and packed in boxes or crates lined with paper, as shown in Fig. 28. Brown (1928) and Work (1936) have reported results of experiments in which celery wrapped with various kinds of paper carried better than unwrapped celery. Work shows that wrapping materially retarded loss in weight and deterioration. Removal of part of the foliage also reduced loss in weight in Work's experiments.

Celery is packed in various sizes and types of containers, from the retail carton holding a few stalks to the large crate holding several dozen. The tendency seems to be toward the smaller sizes of boxes and crates. For shipping long distances, wooden crates still predominate but these vary greatly in size and shape. The standard crate of New York is 20¾ inches long, 16 inches wide, and 22 inches deep, inside measurements, and has a capacity of 7,304 cubic inches. This crate is used to some extent in Michigan and in other northern states. Florida growers use a smaller, flat crate and California growers use a larger, square crate for a large part of their shipments. The size and shape of crates change so rapidly that it is not worth while to give dimensions of those now in use.

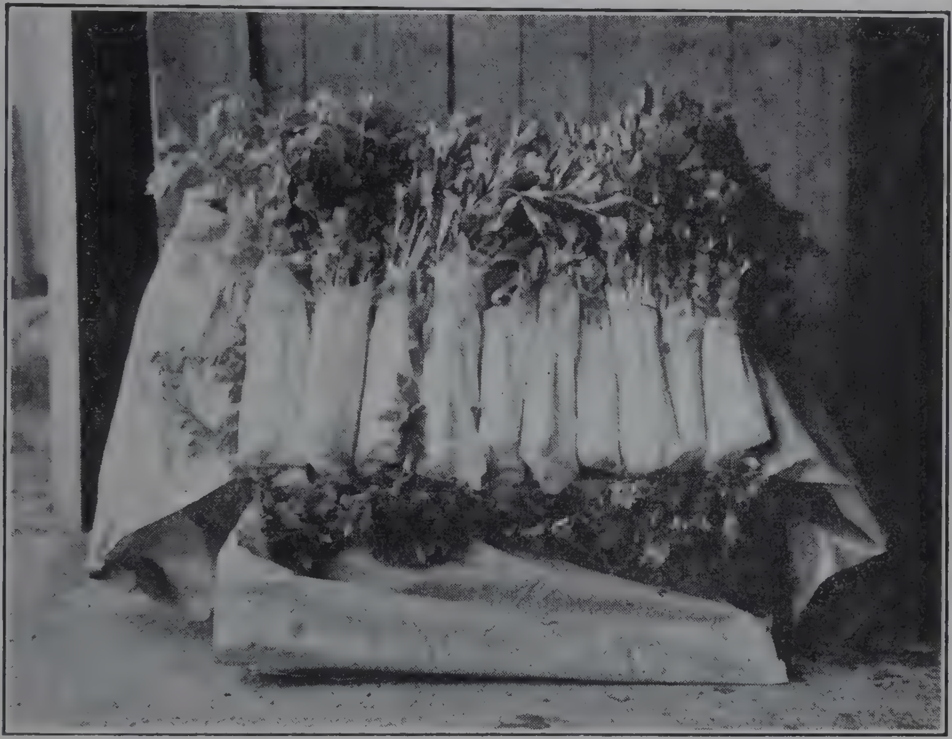

FIG. 28.—Washed celery wrapped in paper and packed in paper-lined box. (*Courtesy Cornell Univ. Agr. Exp. Sta.*)

Storage.—To keep celery successfully for any considerable period it must be free from disease and other injury at time of storage and kept at a low temperature, but not allowed to freeze. Various methods of storage are in use including: (1) trenching in the field, (2) storing in pits, (3) storing in specially constructed storage houses, and (4) storing in cold-storage houses.

1. Trenching in the field is practiced where the celery is to be held for a relatively short period in the fall. By this method 8 to 10 rows of celery are assembled and set with the stalks close together in a shallow trench. The trench is often opened with a plow by running two or more times in the row and then shoveling out the loose soil in the bottom. When the trenching is done to protect the celery against freezing for a short period, soil is thrown over the plants with a plow. For longer storage, 2 months or more, boards are often set along the sides of the trenches and the celery is placed between them. Soil is then banked up along the sides of the trench and a covering of boards is put on.

Often a layer of straw, hay, or other material is placed on the boards and over this a thin layer of soil to prevent the material from being blown away. As the weather gets cold, more soil is added to protect the celery against freezing. Another method of covering the trench is to nail boards together in the form of a V and invert them over the trenched celery. The boards are banked with soil or manure when necessary to prevent freezing.

Any type of trench storage is objectionable because the temperature and moisture cannot be controlled. If a period of wet weather sets in followed by several warm days, the celery may rot in two or three weeks.

2. Storage in pits is practiced by market gardeners in many regions, especially in the vicinity of Boston. Blanching boards are often used for the roofs of these pits and when the boards are 12 feet long the width of the pit is usually 22 to 23 feet. The roof is 7 to 8 feet high at the ridge and 3 to 4 feet high at the eaves. It is supported by one line of posts through the center and two lines halfway between the ridge and the eaves. The ridge is made of 2 by 6-inch planks, while the purlins may be of the same material, or 2 by 4-inch pieces. The sides of the pit may be of earth, or of planks with soil banked against the outside. The roof is covered with leaves, hay, or other material and soil may be placed over this covering.

The celery is set in rows 3 to 4 inches apart, the plants touching in the row. Soil is firmed around the roots to hold the plants in position. Sound celery can be kept in these pits until spring, if proper attention is given to ventilation and temperature. A temperature of 32°F. is considered the best. With a temperature much higher the storage season will be shortened and at a temperature below this there is danger of freezing. The green varieties of celery will usually keep for a longer period than the self-blanching varieties.

3. Storing in specially constructed houses, built partly below ground, is not practiced to the extent that it was formerly. These houses are similar to those built for storing root crops. The celery is placed in the houses in much the same way as in the pits described above. The main advantage of the house over the pit is that the former is a permanent structure while the latter must be made every year.

4. Cold storage is used for a large part of the truck-crop celery that is stored. Considerable celery shipped from California to eastern markets is stored in transit or in cities where it is eventually sold. In New York cold-storage houses in the producing regions are used for storing hundreds of cars of celery for periods of 1 to 2 months or longer. Terminal cold storages also are employed for celery grown in New York, as well as that grown elsewhere. Florida celery is held in cold storage in the markets for short periods.

Cold storage has many advantages over the other methods, especially in the control of temperature and humidity. It is impossible to control either in the trench method of storage, and even in the pit and common storage house it is not possible to keep the temperature down during a period of warm weather in the fall. It requires less labor to store celery in cold-storage warehouses than in the other types of structure. It is packed in crates in the field and is not disturbed until it reaches the market. This method of storage is the most convenient as the warehouses are equipped with elevators, trucks, etc., for handling the celery and they are usually located on a railroad siding so that the product can be loaded for shipment in any kind of weather. This is not true of the other types of storage. In fact, in field storage it is unsafe to remove celery when the temperature is very low on account of danger of freezing and it is very disagreeable work under such conditions.

Most authorities recommend a temperature of 32°F. for the celery storage room and it is the aim of the managers of most cold-storage houses to maintain this temperature. This is probably safe since there is considerable variation in temperature in different parts of the room due to lack of air circulation. It should be borne in mind, however, that when the air is at 32°F. the temperature of the celery in the center of the crate is much higher, and also that celery does not freeze at the freezing point of water. In experiments conducted by Thompson (1917) the temperature of the celery averaged 2° to 3°F. higher than the air at the same height in the storage room. In no instance did the celery freeze, even the outside stalks, unless the air temperature remained below 30°F. for several hours. When freezing occurred, it was in the bottom crates where the temperature was two or more degrees lower than at the height where thermometers are usually located in the storage rooms. Where the thermographs registered a temperature of 28°F. near the floor, there was always some freezing of the outside stalks in the bottom crates, but none in crates above the bottom tier.

Celery in storage, even at an air temperature of 32°F., is active. During the early part of the storage period, normal ripening processes are going on and later there is a breaking down of the cells which is followed by decay. Corbett and Thompson (1925) have shown that changes take place in the cell walls and that there is translocation of sugars and other products from the outer stalks to the inner ones. Microchemical studies, made on celery at weekly intervals during storage, indicate a marked change in the pectic compounds of the middle lamella. The more resistant pectic compounds change to the less resistant ones and these changes are correlated with the observed changes in the celery.

Physical tests showed a marked decrease in resistance during the first week or 10 days in storage. This was followed by slight change during the next few weeks and finally by a sharp decrease in resistance toward the end of storage.

Chemical analyses showed marked changes in sugars and in nitrogen. Both reducing and total sugars in the leaves showed a marked decline from harvest time to the end of storage. The decrease in sugars in the leaves was accompanied by an increase in the stems until toward the end of storage when there was a sharp decline. The decrease of sugar probably was due mainly to translocation to the stems. Soluble nitrogen increased in both leaves and stems from harvest time until toward the end of the storage period, when there was a marked decrease in the leaves and a slight decrease in the stems. Insoluble nitrogen was high in the leaves at harvest time and, in general, decreased from then to the end of storage. At low temperature the changes take place slowly. The aim, therefore, should be to keep the temperature as low as possible without freezing.

Quality in Celery.—Both heredity and environment are involved in quality. It is well known that some varieties are of better quality than others and it is known also that the conditions under which the crop is grown affect quality. Celery, to be classed as of good quality, must be crisp and tender and have a pleasant, sweet, nutlike flavor. Some varieties possess all of these qualities, but those most commonly grown fall far short of meeting the requirements. It has been believed that the size of the fibrovascular bundles is the main factor in stringiness, but Sayre (1929) has presented evidence indicating that this is not true. Some of the tender varieties have small fibrovascular bundles, while others have medium sized and still others have large bundles. Sayre stated that the collenchyma is the only tissue that has any definite relation to stringiness, but Esau (1936) states that both the collenchyma strands and the large vascular bundles constitute the "celery strings." Results of studies reported by Curtis (1938) support the conclusion of Esau. Flavor seems to be influenced more by variety than by environmental factors.

LETTUCE

Lettuce is the most popular of the salad crops, being grown in nearly all home gardens in cities as well as on farms. While a large part of the commercial production is centered in California and Arizona, it is grown for market in many states and is available throughout the year. The value of the commercial lettuce crop in 1937 was greater than any other vegetable crop, except potatoes and tomatoes.

Statistics of Production.—The acreage, production, and value of lettuce grown in the important states, by 5-year periods from 1918 to 1937, are shown in Table XXVIII. California accounted for slightly over two-thirds of the acreage in 1937, and California and Arizona combined accounted for about 80 per cent of it. Only four other states, Colorado, New York, Washington, and Oregon, produced over 2,000 acres. The average annual acreage for the period 1933–1937 was over five times greater than for the period 1918–1922.

TABLE XXVIII.—AVERAGE ANNUAL ACREAGE, PRODUCTION AND FARM VALUE OF LETTUCE GROWN IN THE UNITED STATES BY 5-YEAR PERIODS, 1918 TO 1937

Year	Acres	Yield, crates per acre	Production, crates (000 omitted)	Price per crate	Farm value (000 omitted)
1918–1922	29,544	235.5	6,957	$1.73	$12,016
1923–1927	88,210	174.0	15,360	1.45	22,205
1928–1932	155,270	123.0	19,163	1.59	30,511
1933–1937	153,632	129.0	19,751	1.42	27,973

History and Taxonomy.—Lettuce is probably a native of Europe and Asia and has been in cultivation at least 2,500 years. It is mentioned frequently by ancient writers, some as far back as 500 B.C.

Cultivated lettuce *Lactuca sativa* is related to the wild lettuce *L. scariola,* a common weed in the United States. The two cross readily and are considered by some botanists as belonging to the same species. Lettuce is an annual and belongs to the Compositae or sunflower family.

There are three distinct types of lettuce grown in the United States: head, cutting or leaf, and cos. There is a fourth type, called asparagus lettuce, little known in this country, but resembling the cos type. This does not form a compact head, but is grown for its thick stem. These four types are recognized as botanical varieties or subspecies and are known under the following names: head lettuce, var. *capitata;* cutting or leaf lettuce, var. *crispa;* cos or romaine, var. *longifolia;* asparagus lettuce, var. *angustana.*

Climatic Requirements.—Lettuce thrives best in a fairly cool growing season and hence is grown in the South, in the Imperial Valley of California, and in Arizona during the fall, winter, and early spring. In most sections of the United States it does not produce a good crop during the hottest part of the growing season, but in some of the Northern states, at high altitudes in some of the Western states, and in the coastal regions of California and Washington it is produced throughout the summer. The winter crop is produced mainly in California and Arizona. The most successful production of lettuce during the summer is in irrigated regions with relatively low growing-season temperatures. Here the temperature is favorable and the soil moisture is controlled by irrigation. In regions where irrigation is not practiced the crop often is ruined by lack of rain, or by too much rain at critical periods. The temperature and moisture factors have determined largely the localization of lettuce production on a large scale.

Soil Preference.—Lettuce is grown on practically all kinds of soils from clay loams to sandy loams and mucks. It reaches its highest development on fertile loams, well supplied with organic matter and on good, well-drained muck or peat soil. In New York most of the lettuce is produced on muck soil, considered by growers as almost ideal for the crop. In California lettuce is produced on fine sandy loams, fine sands, silty clay, and silty clay loams. In the Imperial Valley, according to Cosby and Goar (1934), silty clays and silty-clay loams were used more for lettuce production than other classes in 1927.

The soil should be well drained, but retentive of moisture, as the lettuce has a relative small root system. Thorough preparation of the soil is essential to success. When the seed is sown where the crop is to mature the surface should be smoothed by a smoothing harrow or by means of a drag. On muck land a drag, or a roller, is used to smooth the surface for planting.

Where furrow irrigation is used, the land is bedded into low flat beds (4 to 8 or 10 inches) with irrigation furrows between them. The width of the beds varies considerably. In some sections of California, the beds are 18 to 20 inches wide and the furrows are about the same width. With beds of this width, two rows may be planted on each bed.

Manures and Fertilizers.—The lettuce plant is a relatively poor forager and it has a small root system, and for these reasons the surface soil should be well supplied with nutrients. For the same reason, the humus supply of the soil should be maintained. When lettuce is grown on upland soil, manure or soil-improving crops should be used to maintain the soil in good physical condition. Where manure is available at a reasonable price it can be used to good advantage for lettuce grown on mineral soils, but some commercial fertilizer should be used to supplement it. Results of many field experiments indicate that on mineral soils of fairly low fertility, application of about 15 tons of stable manure, supplemented with 50 to 75 pounds of nitrogen, 100 to 150 pounds of phosphoric acid, and 50 to 75 pounds of potash should give good results. When soil-improving crops alone are used to maintain the humus supply, the nutrients should be increased. On sandy soils without manure, the fertilizer should contain at least 100 pounds of nitrogen and 150 to 200 pounds each of phosphoric acid and potash. On silt and clay loams, 50 pounds each of nitrogen and potash and 100 to 150 pounds of phosphoric acid should supply the needs of the lettuce crop.

On recently cleared muck soil that has a favorable reaction, nitrogen is not needed, but both phosphorus and potash are required in considerable quantities. On such soils a fertilizer supplying 100 pounds of phosphoric acid and 150 pounds of potash should be sufficient. An application of 1000 pounds of 0–10–15 fertilizer to the acre is suggested. Muck soils that have been cropped and well fertilized for 10 years or longer usually should have some nitrogen, especially for Big Boston lettuce and for the Iceberg type, when grown during the cool part of the growing season. Less phosphorus and potash are required on muck that has been under cultivation for 10 years or longer than on newly cleared muck. Results of experiments in New York indicate that on old muck an application of 25 pounds of nitrogen, 75 to 100 pounds of phosphoric acid, and 40 to 50 pounds of potash is sufficient for Iceberg type of lettuce grown during the cooler part of the growing season; Big Boston lettuce should have twice as much nitrogen when grown under the same condition. Iceberg grown during mid-summer, when nitrification is rapid, needs no nitrogen and Big Boston requires less than when grown during cool weather.

Soil Reaction.—Results of experiments indicate that lettuce does not grow well on mineral soils that are strongly acid. Hester, Parker, and Zimmerley (1936) reported results of an experiment on sassafras loam soil in which the yield increased as acidity decreased from pH 5.0 to 6.5. The yield was very low at pH 5.0. At pH 7.0 the yield was less than at pH 5.8, 6.0, or 6.5. Chlorosis develops under some conditions when the soil is brought to neutrality by liming. Crist (1928) found that liming a strongly acid soil beyond 25 to 33 per cent of the lime requirement progressively reduced the growth. Lettuce is grown satisfactorily in some regions on alkaline soils, but it is not desirable to use lime to bring the reaction to neutral or alkaline.

Considering the experimental evidence, it seems safe to recommend that lime be used only where it is known that it is needed. Test of the soil acidity should be made, and if the soil is strongly acid lime should be used in varying quantities to determine how much is needed.

Growing Plants for Transplanting.—For a very early crop of lettuce in the North, the seed is sown in a greenhouse or hotbed several weeks before time for setting in the field. If the plants are to be taken directly from the seedbed to the field 5 to 6 weeks is sufficient time to allow between seed sowing and outdoor planting. This method is not satisfactory and the more common practice is to sow the seed 8 to 10 weeks before the date for field setting and to transplant the young plants when they are about 3 weeks old. The plants are spaced 1½ by 1½ or 2 by 2 inches apart either direct to the soil of the greenhouse, hotbed, or cold frame, or preferably into flats. They should be hardened before being set in the field and this is often done by moving them into a cold frame and exposing them gradually to lower temperatures, by withholding water, or by both of these methods.

Planting in the Field.—Hardened plants and seeds may be planted as soon as hard freezes are over. In regions where hard freezes do not occur, but where the summers are hot, as in Arizona, in the Imperial Valley of California, and in the milder sections of the South, lettuce is grown during the winter and seed is planted in the fall and early winter. In the Salinas-Watsonville district of California the cool summers and mild winters make it possible to mature lettuce throughout the period from the latter part of March to late December. In this region planting is done in late winter and at intervals through the spring and summer. Lettuce is grown in summer also in the Puget Sound region of Washington and at high elevations in Colorado and some of the other western states. In most other sections of the United States, planting is done as early in the spring as possible for an early summer crop and in midsummer or later for a fall crop.

Lettuce seed does not germinate well at temperatures above 80°F. Borthwick and Robbins (1928) have shown that if the seed is placed in thin layers between moist burlap and placed on ice for 4 to 6 days, germination will be good when planted in moist soil at a temperature of 86°F. or higher. The seed should have good aeration during this period and should be allowed to dry before being planted.

Commercially, the seed is sown with drills either single drills operated by hand or gang seeders, with two, three, four, or more drills drawn by horses, mules, or tractors. With rows spaced 14 or 18 inches apart, 1½ to 2 pounds of seed should be sufficient to plant an acre; for rows spaced farther apart less seed is required. As soon as the plants are well established, they are thinned to stand from 10 to 18 inches apart, the closer spacing being allowed for small-growing varieties and the wider spacing for large-growing lettuce such as some of the strains of New York. The thinning should not be delayed or crowding will produce weak spindling plants. In some sections where lettuce is grown on muck soil, the plants removed in thinning are transplanted to other beds, but it is doubtful if this is a good practice. The plants that are left usually produce a better crop than those transplanted and the latter operation is probably more expensive than thinning.

Where plants are set out, the rows are spaced the same distance apart as for seed sown direct to the field. In the rows they are given about the same space as the thinned plants. The plants are set by hand, the method depending on the kind of soil and the character of the plants. If the plants have been transplanted prior to going to the field, a trowel is often used or a small shallow furrow may be made with the plow attachment of the hand cultivator. On muck soils the hole for the plant is usually made by hand since the soil is very light.

Cultivation.—Frequent, shallow cultivation is important for lettuce as the plants cannot compete successfully with weeds. Their root system is very small and many of the roots are near the surface; therefore, shallow cultivation is important. When weeds are troublesome, the knife attachments of hand cultivators or scuffle hoes are better than the cultivator teeth. The knives and scuffle hoes cut off the weeds below the surface and leave a thin layer of mulch, without injuring the roots. When the surface soil is loose and no weeds are present nothing is gained by continuing cultivation. On the other hand, cultivation under these conditions may be injurious by bringing moist soil from below, to the surface where it will dry out, and, also by breaking the roots.

Hand weeding between the plants in the row is usually necessary and this is a tedious and expensive operation. On muck soil this is usually done with the hands as the soil is light, but on upland soils hoes are often used for a part of the work.

Varieties.—The great popularity of lettuce and the varied conditions under which the crop is grown are probably responsible for the large number of varieties and the still greater number of varietal names. Tracy (1904) in his classification of lettuce recognized over one hundred distinct varieties. Lester L. Morse (1930), one of the largest lettuce seed growers, states that twenty-two varieties cover practically all of those grown in America. Lettuce varieties have been classified by various authorities, the most complete being the following worked out by Tracy:

Class I. Butter varieties.
  Subclass I. Cabbage-heading varieties.
    Color Division I. Plants wholly green. Philadelphia Butter, Black Seeded Tennis Ball, etc.
    Color Division II. Plants tinged brownish, larger part green. California Cream Butter, Big Boston, White Seeded Tennis Ball, etc.
    Color Division III. Plants brownish, small portion only greenish. Brown Head Eureka, Sugar Loaf.
  Subclass II. Bunching varieties.
    Color Division I. Plants wholly green. Oak-leaved, Earliest Cutting, Golden Heart, Lancaster.
    Color Division II. Plants brownish.
Class II. Crisp varieties.
  Subclass I. Cabbage-heading varieties.
    Color Division I. Plants wholly green. Brittle Ice, Hanson, New York.
    Color Division II. Plants tinged with brownish, large part greenish. Density, Iceberg, Marblehead, Mammoth.

- Color Division III. Plants brownish, small part only greenish. Chartier, Mignonette, Sugar Loaf.
- Subclass II. Bunching varieties.
  - Color Division I. Plants wholly green. Black-seeded Simpson, Boston Curled, Grand Rapids, White-seeded Simpson.
  - Color Division II. Plants brownish, small part only greenish. American Gathering, Chartier, Prize Head.

Class III. Cos varieties.
- Subclass I. Spatulate-leaved varieties.
  - Heading Division I. Self-closing.
    - Color Division I. Plants wholly green. Dwarf White Cos, Express Cos, Giant White Cos, Green Cos, Paris White Cos, Prince of Wales Cos.
    - Color Division II. Plants brownish. Red Winter Cos.
  - Heading Division II. Loose-closing. Bath Cos.
- Subclass II. Lanceolate-leaved varieties. Asparagus.
- Subclass III. Lobed-leaved varieties. Asparagus Lobed-leaved.

Of the butter varieties only the Big Boston (Fig. 29) and White Boston are grown commercially to any appreciable extent. Other well-known varieties of this type are California Cream Butter, Tennis Ball, Deacon, and Wayahead. The varieties of the butter type are of much less commercial importance than the varieties of the crisp-head type.

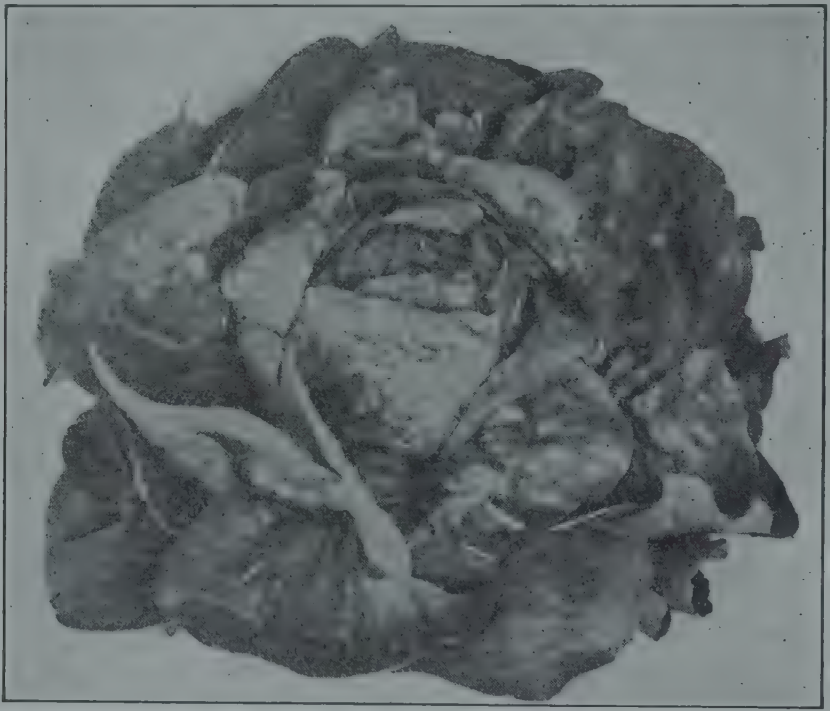

Fig. 29.—A good head of Big Boston lettuce, the best known of the butter varieties. (*Courtesy of C. C. Morse & Co.*)

Of the crisp-head varieties (Fig. 30), the New York or Wonderful, including hybrids between this and other varieties, is by far the most important variety of lettuce grown in the United States. There are many strains of New York identified by number as New York 12, New York 515 and others and also many strains known under the name Imperial with letters or numbers as Imperial 1, 2, 3, 4, 5, 2–50, and Imperial C and F. The strains are being improved continuously and new names or new numbers given. A new strain known as Imperial 44 has given great promise as a commercial lettuce in New York and other eastern states. The term Iceberg has been applied to the commercial strains and varieties of crisp-head lettuce, namely New York; this is unfortunate since there is a distinct variety called Iceberg. Strains of New York and Imperial are known under many different names. Other crisp-head varieties are Hanson, Crisp-as-ice, Mignonette, and Iceberg. The Mignonette is one of the smallest of the heading varieties. It is excellent in quality, but is not important as a commercial variety because of its small size, reddish brown color, and its habit of going to seed quickly.

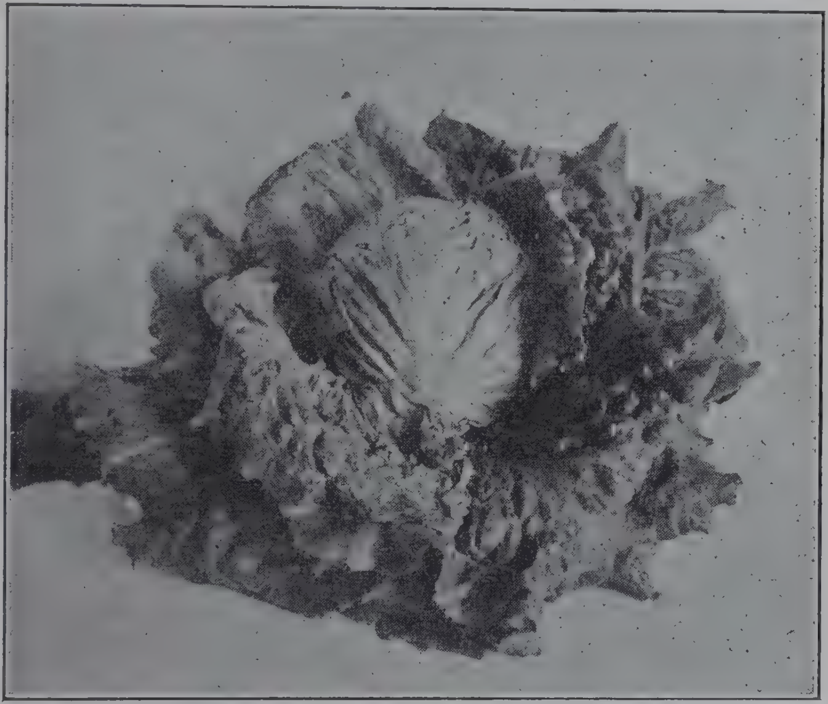

Fig. 30.—An ideal head of lettuce of the crisp class. (*Courtesy of C. C. Morse & Co.*)

Among the leaf varieties, Grand Rapids (Fig. 31), Prize Head, Early Curled or White-seeded Simpson, and Black-seeded Simpson are the most popular. These are not grown to any great extent in the field, although they are very popular in the home garden. For growing in greenhouses during the winter the Grand Rapids is used almost exclusively except in sections of the East as in the vicinity of Boston and Rochester.

White Paris Cos, Fig. 32, (White Cos, Paris White Cos) is the most important variety in the cos class, although Express Cos and Giant White

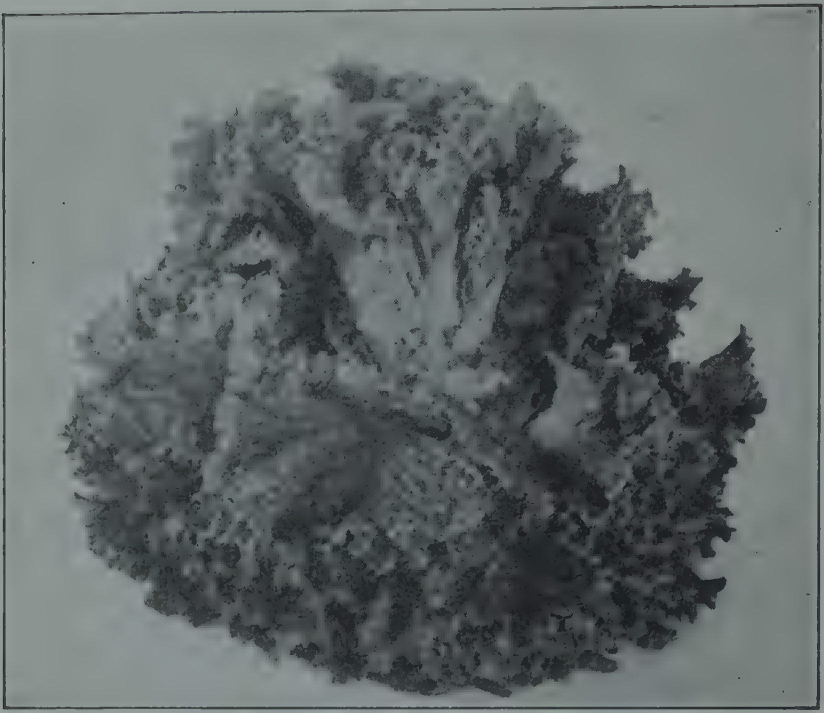

FIG. 31.—Full-grown plant of Grand Rapids lettuce, one of the best representatives of the bunching varieties. (*Courtesy of C. C. Morse & Co.*)

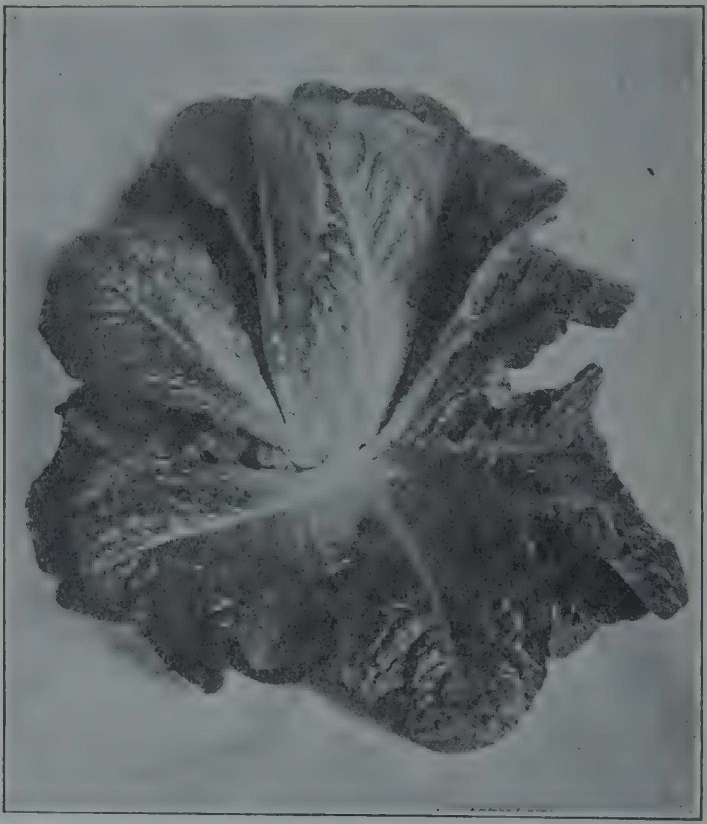

FIG. 32.—Cos lettuce showing the general character of the head and the shape of the leaves. (*Courtesy of C. C. Morse & Co.*)

Cos are grown to some extent. Cos lettuce is becoming more popular each succeeding year and is being grown at the present time on a fairly large scale in various sections of the United States. Considerable acreages are grown on the muck soils in New York and in other states.

Diseases.—Lettuce is attacked by a large number of diseases, but only a few of them are important enough to cause serious losses. Most of them are difficult to control and some are not controlled at all. In fact, there are no thoroughly good control measures for any of them since the nature of the lettuce plant makes it difficult to apply the usual fungicides. The diseases that are known include the following: lettuce drop, bottom rot, gray mold-rot, brown blight, anthracnose, downy mildew, lettuce stunt, bacterial wilt, bacterial rosette, marginal blight, bacterial rot, mosaic, septoria leaf spot, cercospora leaf spot, fusarium root-rot, "rabbit ear," white heart and tipburn. Only a few of these will be discussed.

LETTUCE DROP.—This disease is caused by two species of *Sclerotinia, S. libertiana* Fuchel and *S. minor* Jagger. It is found in practically all parts of the United States, but is seldom very serious in field-grown lettuce in the North. In Florida and in other southern states, as well as in the central states, it sometimes causes serious losses.

This disease usually begins on the stem near the ground and spreads both upwards and downwards. Plants attacked by it show a characteristic drooping or dropping of the leaves. The attack of the fungus cuts off the water supply to the leaves when the petioles are invaded and this results in wilting and a dropping of the leaves. The parasite rapidly ascends the stem and kills the leaves. Under moist conditions the fungus produces a white mycelial growth on the foliage. In this growth appear black sclerotia varying in size from that of a cabbage seed to the size of a pea seed. The organisms attack other plants.

Crop rotation, eradication of weeds, and frequent shallow cultivation to keep the surface dry lessen the chances of the fungi to cause infection.

BOTTOM ROT.—The organism causing this disease is now known as *Rhizoctonia solani* Kuhn. The fungus causes damping-off of seedlings as well as producing other disease on many host plants. On lettuce plants in the field the first parts affected are the leaf stems that touch the ground. Two characteristic symptoms are the rusty, slightly sunken lesions on the petioles and midribs, and the slimy brown rot on the leaf blade. The disease may spread throughout the head. Later the tissue dries up leaving a black mummified plant.

The parasite lives in the soil on growing plants and on plant refuse. It develops rapidly under moist, warm environment.

Control measures recommended include: (1) long rotations with crops such as sweet corn, potatoes, onions, tomatoes, beets, and other crops not attacked by the fungus, (2) removal of all refuse as soon as the crop is harvested, (3) shallow cultivation after rains to hasten the drying of the surface, and (4) dusting with a fungicide. Good results have been obtained by dusting the soil under the plants with ethyl-mercury phosphate dust, and New Improved Ceresan. Two or three weeks before harvest, the dust is blown under the plants with a special lettuce duster applying 12 to 15 pounds of dust to the acre. Several types of dusters have been described and illustrated by Townsend and Newhall (1932). Where the disease is severe two applications of the dust may be desirable. Strains of the New York variety are less affected by bottom rot than are the strains of Big Boston.

In the greenhouse, soil sterilization is effective and practicable.

Gray Mold-rot.—This is caused by a species of *Botrytis*. It is not serious generally, but under some conditions it is of great importance. The mold-rot may attack the plants at any stage of growth in the field, in the greenhouse, or in transit. When it attacks the plants in the seedling stage the disease resembles common damping-off. More commonly the rot is found on fully developed or partly developed plants. The disease appears as a soft, dark, decayed area on the base of the stem. It develops rapidly and when the petioles are rotted the leaves wither. On the mature head the inner, tender leaves often become a slimy mass. Sometimes the disease appears on one side of the plant. After the head is rotted, flat cylindrical sclerotia may be found among the decayed mass.

In the greenhouse this disease can be controlled by regulating the temperature and the ventilation. The fungus grows best at temperatures between 68° and 75°F., so that a relatively low temperature at night is desirable. Keeping the surface of the soil relatively dry during the day will aid in controlling this trouble in the greenhouse.

Brown Blight.—The cause of this disease is unknown. Plants affected by it in the early stage of growth assume a mottled, yellow color, become rosetted, and do not head. If the disease appears after the heads form, the entire plant may become yellowish, and dead, brown irregular streaks may appear in the outer leaves. Infected leaves usually dry up and turn brown.

Brown blight is known to occur in Arizona and California. It was so severe in the Imperial Valley about 1920 that it was thought that lettuce could no longer be grown profitably in that area. Through the work of Ivan C. Jagger of the United States Department of Agriculture strains of lettuce have been developed that are resistant to the disease. Jagger (1931) reported that search for individual plants resistant to brown blight in fields where the crop was destroyed by the disease resulted in the development of resistant strains which were introduced under the names Imperial No. 2, No. 3, and No. 6. These were developed from resistant plants of New York. Since that time hybridization and selection have resulted in the development of other strains some of which are resistant to both brown blight and downy mildew. These strains are generally used in the important lettuce-producing regions of California.

ANTHRACNOSE.—The fungus causing this disease is known as *Marssonina panattoniana.* All parts of the plant may be infected, the disease usually progressing from the outside to the inner leaves. The spots start as small, roundish, water-soaked areas which become brown in color. The affected tissues dry up and drop out, giving the leaf a shot-holed appearance. On the petiole and midrib the sunken areas are irregular in outline.

Rotation of crops and destruction of diseased plants are recommended as control measures. In the greenhouse, sanitation and maintenance of a relatively high temperature will aid in controlling anthracnose.

DOWNY MILDEW.—This disease, caused by *Bremia latucae,* is not serious in the field in many sections of the United States, but in California it has caused considerable loss. It is of importance because the edible leaves are attacked and in transit the affected leaves offer a suitable substratum for the growth of saprophytic organisms causing soft rot.

Control measures recommended in the field include the use of resistant varieties, crop rotation, and eradication of wild lettuce, which is said to be a host for the organism. In the greenhouse careful attention to watering and ventilating is important. The foliage should be kept as dry as is feasible.

LETTUCE STUNT.—Stunt is caused by a species of *Pythium.* This disease ordinarily causes no serious losses. Plants affected with stunt are dwarfed, the foliage becomes darker than that of healthy plants, and the central leaves may not develop. The outer leaves die and shrivel and the death of the entire plant finally results. The vascular bundles become blackened.

The fungus lives in the soil, but is not carried on the seed. Infection may take place as soon as the seed germinates. Cool weather is favorable for the development of disease.

No methods of control of this disease in the field are known.

MOSAIC.—The mosaic generally is not a serious disease of lettuce, but in a dry season when aphids are abundant there may be considerable loss. Jagger (1921) has shown that it is transmitted from diseased to healthy plants by aphids, and Newhall (1923) showed that the virus also lives on the seed. While no definite control measures are practiced, the use of clean seed and controlling the insect carriers would seem to be the logical methods to employ.

TIPBURN.—This disease frequently is very serious in the field, causing severe losses under some conditions in all of the important lettuce-producing sections. The leaves of affected plants turn brown along the edges, thus rendering the heads undesirable on the market.

This disease apparently is not caused by any parasitic organism, but rather by unfavorable environmental conditions. Thompson (1926) presented evidence that indicates that high temperature and high humidity are favorable to tipburn. Results of his studies do not bear out the common belief that rapid loss of moisture from the leaves is the important factor. In fact, he reports that tipburn developed in the experimental greenhouse only at night, when transpiration was lowest and the atmospheric humidity was highest. Leaves injured by tipburn were usually in a turgid condition. Thompson expressed the belief that tipburn is due to excessive accumulation of respiratory products.

Tipburn develops most on rapidly growing succulent plants. It is seldom troublesome during cool weather even though the atmospheric humidity is high.

No control measures are known and the prospects of developing satisfactory control are not bright. It is not feasible to control the environmental conditions that cause the trouble. Development of varieties resistant to tipburn does not give great promise since the disease is associated with succulence—a desirable quality.

Premature Seeding.—Seedstalks often develop before the plant is full grown and this results in loss to the grower. Results of experiments reported by Thompson and Knott (1933) indicate that high temperature is the most important factor involved in premature seeding of lettuce. Seeding may take place during the cool weather of early fall if the plants have been subjected to high temperature for a considerable period earlier in their growth. In these experiments, length of day had no appreciable effect on seedstalk development.

Insects.—The most important insect pests of lettuce are various species of plant lice or aphis. Control measures for these are the same as for the spinach aphis. The cabbage looper also attacks lettuce. For description of this insect and control measures suggested see under "Cabbage." Cutworms sometimes injure lettuce early in the season and may be controlled by poison mash as recommended in Chapter XIII.

Harvesting.—The stage of development at which lettuce is harvested depends on the type and the purpose for which it is grown. Head lettuce, when grown for market, is allowed to grow to full size and to develop a solid head. When grown for home use it is often harvested before the head is well formed, but when used as leaves there is no advantage in growing a heading type. Leaf lettuce grown for home use is harvested at any time after the plants get large enough for use. A common practice is to thin the plants at various times, removing the largest ones for use and leaving the small ones to develop. In this way one planting will supply the table for a considerable period. When grown for market, leaf lettuce is usually allowed to develop to full size, unless the price is very high prior to that time, in which case the plants are cut any time after they become half grown. Of course, a larger yield will be produced on a given area if the plants are allowed to develop to full size than if cut earlier, but the returns may be as high under the latter practice.

Lettuce is cut usually with a long-handled sharp knife. Where the lettuce drop is serious it is best to make the cut above the leaves resting on the ground so as to eliminate the disease spores and prevent their spread throughout the crate. When drop is not present and when the packing is to be done in a packing shed, the plant may be cut just below the surface of the ground. In this case the trimming is done in the packing shed.

Ramsey and Markell (1917) have shown that by careful cutting and removing the bottom leaves of lettuce grown in fields where "drop" is serious, it arrives on the market in much better condition than if cut in the ordinary manner.

It is best not to harvest the lettuce immediately after a rain or while the dew is on it. When the plants are full of water the leaves are crisp and brittle and break easily in handling.

Grading.—Lettuce grown in the West for shipping to markets in the East is graded carefully and usually only good heads are packed. In the eastern states grading is not done so well as it should be. The western grower is forced to grade because the high freight charge does not permit of shipping inferior lettuce. Lettuce should be graded by all growers and only good heads should be shipped. The Bureau of Agricultural Economics has formulated tentative grades, U. S. Fancy, U. S. No. 1, and U. S. No. 2. These grade specifications can be obtained from the U. S. Department of Agriculture and from the state marketing agency in most states. Since the specifications are changed from time to time they are not given here.

Packing.—Before being packed, lettuce should be trimmed to remove the diseased and dirty leaves, and separated into grades, in case any separation is made. In some sections the packing is done mostly in the field; in others the lettuce is hauled to a packing shed where it is trimmed and packed. In packing head lettuce in crates or boxes, the bottom layer is placed with the stem end down and the others reversed, thus protecting the heads in transit. When baskets and hampers are used the same method of packing may be used, or all of the heads with the exception of the top layer may be placed with the stem end down. The top layer is always placed with the stem end up.

In the eastern part of the United States most of the head lettuce that is shipped is packed in a lettuce box holding two layers. Usually two dozen heads are packed in each box, but when the heads are small more than that are sometimes packed in the box. The standard lettuce box in New York is 19 by 16 by 7½ inches inside and has a capacity of 2,280 cubic inches. This box, or one of approximately this size, is used in most of the eastern states. The lettuce crates used in the West are larger. Several sizes of crates are in use in the West and the number of heads packed usually range from 3 to 5 dozen, although the variation is from 2½ to 7 dozen heads. These crates are lined with waterproof paper to keep the lettuce crisp and to prevent mechanical injury. Three layers of heads are packed in these crates with the stem end up. Cracked ice generally is placed between the layers and the crates are top-iced after being loaded into the refrigerator cars.

Storage.—Lettuce is not usually considered a storage product, but under good refrigeration it can be kept for a period of 3 to 4 weeks provided it arrives at the storage house in good condition. For storage it is packed as for market and is placed in cold storage where the temperature is kept at about 32°F. Storage is of great importance since it often happens that the market is glutted for a few weeks and then is nearly bare for a period. Storage prevents this glut and tides the market over the period of slack production. This helps both the producer and the consumer.

In some sections lettuce is hauled direct from the field to the storage house, where it is precooled before it is loaded into cars. This may be a good practice, but the same results can be secured in a properly constructed refrigerator car. Well-constructed cars with basket bunkers and false floors give good refrigeration and rapid cooling, especially if salt is used with the ice at the first icing. Precooling by placing in cold storage is not important, if the lettuce can be loaded direct into cooled cars equipped with basket bunkers and false floors. In fact it is probable that the cooling is as rapid in the type of car mentioned as in the average cold-storage room where there is no forced circulation of air.

ENDIVE

Endive (*Cichorium Endivia* Linn.) belongs to the Compositae or sunflower family and is probably of East Indian origin. It was used as food by the Egyptians at a very early period, being referred to by Pliny, who states that it was eaten as a salad and potherb in his day. As now grown endive is eaten mainly as salad, taking the place of lettuce. It is grown mainly by market gardeners near large cities, where it is consumed largely by the foreign population.

Culture.—The general methods of culture of endive are practically the same as for lettuce. It is grown mainly for fall and early winter markets, although it can be produced as an early summer crop by starting the plants under glass, or even by sowing the seed in the open very early in the spring. For the fall crop in the North the seed is sown in July or August. In the South it can be grown as a winter crop. If planted in the spring in the North the seed may be sown as soon as hard freezes are over since the crop will withstand light freezes. The plants make the most satisfactory growth during cool weather.

The distance of planting is about the same as for lettuce, the rows being 15 to 18 inches apart for hand cultivation, with the plants thinned to stand 6 to 10 inches apart in the row.

Any soil suitable to lettuce culture is satisfactory for endive. Rapid growth is important in order to procure tender, crisp leaves. The same soil treatment recommended for lettuce is suggested for this crop.

Blanching.—When the crop is grown for salad the leaves should be blanched to reduce the bitterness and to render them more tender. Blanching also improves the appearance of the leaves when they are to be used for garnishing.

Blanching requires 2 to 3 weeks, or even longer in cool weather. Any method that excludes the light from the central leaves and keeps them dry is satisfactory. The most common method is to gather all of the leaves into a bunch and tie them near the top. If rains or cloudy weather follow the tying, it is important to examine the crowns frequently to see that they are not decaying. After the inner leaves are blanched, they should be harvested quickly to prevent decay. Covering the plants with boards, hay, straw, or other material is sometimes practiced. When grown in the greenhouse great care must be taken to keep the house cool and the atmosphere relatively dry during blanching. Paper-covered frames have been recommended for blanching endive by S. N. Green.[1] These frames exclude the light and allow a fair circulation of air.

Varieties.—There are two types of endive, the curled or fringed-leaved and the broad-leaved varieties. The former is more ornamental than the latter. The most popular varieties of the curled type are Giant Fringed, Green Curled Winter, and White Curled. Broad-leaved Batavian is the best known of the broad-leaved type and this is used mainly in stews and soups and as a potherb.

CHICORY

Chicory (*Cichorium intybus* Linn.), also known as French endive, Witloof, Witloof chicory, and succory, is probably a native of Europe and Asia. It has been in use as a salad plant from time immemorial, but was probably not cultivated by the ancients. It was not mentioned in the descriptive lists of vegetables until the thirteenth century.

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[1] Ohio Exp. Sta., *Mo. Bull.* 32.

At the present time chicory is grown mainly for its leaves used in salad and for its root as an adulterant for coffee. In Europe the green leaves are used as potherbs to some extent.

Culture.—When grown for salad the seed is usually planted in spring or early summer in rows 15 to 18 inches apart and the young plants thinned to 4 or 5 inches. Too early planting may result in development of the flower stalk and a root of no value for forcing. Any soil suitable for beets, carrots, and parsnips is satisfactory for chicory. The cultivation and care throughout the growing season are the same as for parsnips. On the approach of cold weather the roots are lifted, or plowed out, and the tops cut off about 2 inches above the crown. The roots are then stored in a cool place where they will remain until needed.

Forcing.—When chicory is used as a food in the United States it is grown largely as a forced crop, and a pure forcing strain should be selected. The crop may be forced under greenhouse benches, in cellars, or out of doors. A temperature of 50° to 60°F. is usually maintained. At a higher temperature the heads are not so solid and there is a tendency to shoot up too rapidly.

The roots usually vary considerably in size and should, therefore, be graded before they are planted. It is desirable to make three or four grades based on length and size. Roots of each grade should be cut to a uniform length so that all of the crowns will be covered to the same depth. The size of the head corresponds to the size of the root used. Very large roots produce large heads many of which are often made up of small divisions. Some good, solid heads develop from the very large roots, but they are generally too large for the best market use. Medium to large roots produce heads of the best market size while small roots yield too many small straight heads. A head 4 to 5 inches long and weighing 2 to 3 ounces is the most desirable.

In preparing the roots for forcing, the slender tips are cut off. They may be taken from storage for forcing at any time from late fall until spring; for a succession of heads, new plantings should be made every two or three weeks. The roots are set in a trench in a sloping direction with the crown about even with, or below, the surface. They are placed close together and the crowns are covered with fine soil, sand or sawdust to the depth of 6 to 8 inches. This covering excludes the light and prevents the leaves forming the head from spreading, making the head solid and compact. Before covering, the roots and the soil below should be watered. One or two later waterings may be necessary but the soil above the crowns should not be soaked. With the proper temperature 3 to 4 weeks are usually required to develop good heads, but at high temperatures the heads will push through the covering earlier.

Good chicory may be grown in outdoor trenches. These trenches should be at least 18 inches deep and 12 to 18 inches wide. The roots are set and covered as described above. Over the covering of sand, soil, or sawdust is placed fresh horse manure to the depth of about 2 feet and extending about 1½ feet on either side of the trench. The manure furnishes the heat and protects the heads against freezing.

Chicory is harvested by cutting off the head at the base. The outside leaves are pulled off and the heads are packed in baskets. The French and Belgian product is shipped in 20-pound baskets with the heads packed in layers. A smaller package is desirable and the 3-pound climax basket has been used in this country.

PARSLEY

Parsley (*Petroselinum hortense*) is the most popular of the garden herbs grown in this country. The leaves are used for flavoring, for garnishing, and to some extent for salads. The plant is a biennial, or short-lived perennial of the Umbelliferae family, and is a native of Europe. It has been in cultivation for over two thousand years.

Culture.—Parsley seed is slow to germinate, and for this reason it is often sown in the greenhouse, hotbed, or specially prepared bed in the open. The young plants are then transplanted where they are to grow to edible maturity. The plants are hardy and may be set out as early as cabbage. In the North, seed is commonly sown outdoors early in the spring and at intervals during the growing season. In the South, the crop is grown mostly during the winter and spring. When grown commercially the rows are spaced about 15 inches apart and the plants given a space of 4 to 8 inches in the row.

Parsley is grown as a forcing crop in the greenhouse, hotbed, or cold frame during the winter and spring. In the vicinity of Norfolk, Va., acres of parsley are grown in frames during the winter for the northern and eastern markets. Near many of the large cities considerable parsley is grown in greenhouses and hotbeds for supplying the local markets.

The cultivation of parsley does not differ from that usually given other small-growing plants. Clean, shallow cultivation throughout the season is recommended.

Varieties.—There are two distinct forms of parsley grown for its foliage, the plain leaved and the curled, the latter being the most popular in this country. The best known varieties are Moss Curled, Extra Double Curled, Fern-leaved, and Curled Dwarf. The plain-leaved parsley has as good flavor as the curled, but is not so attractive, hence is little grown. In addition to the forms grown for their foliage a turnip-rooted parsley is grown for its edible root. This is grown in the vicinity of some of the large cities, where it is sold mainly to the foreign population. The culture of turnip-rooted parsley is about the same as for carrots.

Harvesting.—In harvesting parsley only a few leaves are picked from a plant at one time. By this method the plant continues to produce a marketable product for several weeks.

The leaves are tied into small bunches for market, and, when shipped long distances, the bunches are packed in baskets, hampers, or barrels. Crushed ice placed in the package as described for spinach is an advantage in preventing heating and decaying in transit.

CHERVIL

Chervil or salad chervil (*Anthriscus Cerefolium*) is an annual plant very much like parsley, popular in Europe, but little grown in this country. It is used for garnishing and flavoring. The curled-leaved varieties are the most popular because of their attractive appearance.

The plant is grown in very much the same way as parsley and the leaves are ready in 6 to 8 weeks from seed sowing. It does not thrive in hot weather, therefore, should be grown as a spring or as a fall crop. It is hardy and will withstand the winters in the North if given the protection of a cold frame, or even a covering of straw or similar material. The plant grows to the height of 18 inches to 2 feet, but the foliage is usually harvested when young.

CRESS

Cress, garden cress (*Lepidium sativum* Linn.), is an annual of the Cruciferae or mustard family and is a native of Europe. It is a cool-weather plant grown for its root leaves. Seeds are sown as soon as the ground can be prepared in the spring. A cool, rich soil should be chosen, for rapid growth is essential to good quality. The plant quickly runs to seed in hot weather. Cress seed is usually planted in rows 12 to 15 inches apart and the plants thinned as needed for the table.

The leaves are used in salads and garnishings and are usually ready for use in 6 to 8 weeks from the sowing of the seed. If the leaves are removed without injuring the crown the plant continues to bear.

Other species of cress, belonging to the genus Barbarea, are rarely grown in this country, although they are cultivated to some extent in Europe. The spring cress (*B. verna*) is a biennial, but when grown under cultivation it is treated as an annual, or as a winter perennial, the seeds dropping in summer produce plants that send up flower stalks the following spring.

WATER CRESS

Water cress (*Roripa nasturtium-aquaticum*) is a perennial, rooting at the joints, thriving in very moist places and in running water. It is readily propagated by seeds and by pieces of the stem. While water cress is commonly grown along streams or ditches fed by springs, it can be grown in moist soil in the garden, in hotbeds, or in greenhouses. When grown in gardens or in forcing structures, the seeds may be started in a well-prepared seedbed and the young plants transplanted, or pieces of stems may be used for starting a bed. As commercially grown, out of doors, it is common practice to plant it along streams or ditches, a stream often being divided so as to extend the planting area. It is important that the water be pure and clean. When once established, it will persist indefinitely if it is not harvested too closely.

CORN SALAD

Corn salad or Fetticus, sometimes called Lambs lettuce (*Valerianella olitoria*), is used both as salad and potherb, but chiefly the former. It is a native of Europe, where it grows wild among the corn (grain), hence the name "corn salad." It is a hardy cool-season crop which is of easy culture except during hot weather. For an early crop in spring, the seeds are often sown in the fall, in drills 18 inches apart and the planting covered with a mulch of straw or other material. The leaves may be blanched, but they are usually eaten green. Corn salad is sometimes cooked and served like spinach, but more often it is used as a salad. It is rather tasteless and is not so popular as other salad crops.

CHAPTER XIX

COLE CROPS

- Cabbage
- Cauliflower and Broccoli
- Sprouting Broccoli
- Brussels Sprouts
- Kohlrabi
- Chinese Cabbage

All cole crops are hardy and thrive best in cool weather, being grown in the South mainly during the winter. The crops in this group are closely related, belonging to the same genus (Brassica), most of them to the same species. The cultural requirements for all the crops in the group are very similar and many of the same diseases and insects attack them all. Kale and collards are cole crops but for convenience they are included with other potherbs or greens.

CABBAGE

Cabbage is by far the most important member of the genus Brassica grown in the United States and, in fact, is one of the important vegetable crops. It is grown by market gardeners in all sections of the United States, and by special vegetable growers and general farmers in many regions. Cabbage is grown in home gardens, both on the farms and in villages and small cities.

Statistics of Production.—The general trend of production of cabbage has been upward as is shown in Table XXIX, but the percentage increase in 20 years has not been so great for cabbage as for celery, lettuce, spinach, and many other perishable crops. The general trend in price per ton has been downward as production increased.

Table XXIX.—Average Annual Acreage, Production, and Value of Cabbage Grown for Market and for Manufacture by 5-year Periods, 1918 to 1937
(U. S. Dept. Agr. *Mimeographs* and *Crops and Markets*)

Years	Acres	Yield per acre, tons	Production, tons	Price per ton	Value (000 omitted)
1918–1922	125,228	7.8	973,222	$18.73	$18,232
1923–1927	134,566	8.4	1,135,240	16.57	18,814
1928–1932	149,150	6.9	1,026,900	16.06	16,488
1933–1937	182,068	6.25	1,138,920	13.71	15,616

There has been a marked increase in production of cabbage during winter in Texas. In 1919, that state produced 4,329 acres and 36,000 acres in 1937. There were increases also in Virginia, North Carolina, South Carolina, Mississippi, and Louisiana; this winter production has had a marked effect on the demand for stored cabbage grown in the Northern states. Statistics on acreage, yield, production, price, and value of cabbage grown in the 13 leading states in 1937 are given in Table XXX.

TABLE XXX.—ACREAGE, PRODUCTION, AND VALUE OF CABBAGE GROWN IN 13 LEADING STATES IN 1937, ARRANGED IN ORDER OF ACRES GROWN
(*Crops* and *Markets*, December, 1937)

State	Acres	Yield per acre, tons	Production, tons	Price per ton	Value (000 omitted)
Texas	36,000	4.3	154,800	$10.10	$1,563
New York	30,650	7.0	216,000	12.55	2,710
Wisconsin	16,760	6.1	101,700	11.05	1,124
Pennsylvania	10,500	7.8	82,200	14.33	1,178
California	8,200	6.4	52,500	15.10	793
Virginia	7,800	6.0	46,600	12.06	562
North Carolina	7,500	6.3	47,100	12.21	575
Michigan	6,440	5.8	37,600	15.00	564
Mississippi	6,400	5.0	32,000	30.81	986
New Jersey	6,300	5.7	35,900	15.99	574
Louisiana	5,500	3.3	18,200	23.02	419
Colorado	5,200	10.6	54,900	10.60	582
South Carolina	5,200	7.5	38,900	15.04	585

History and Taxonomy.—Cabbage is found in the wild state on the chalk rocks of the seacoast of England, on the coasts of Denmark and northwestern France, and in various other localities from Greece to Great Britain. It has been known from earliest antiquity and was probably in general use 2,000 to 2,500 B.C. It was held in high esteem by the ancient Greeks and is said to have been worshipped by the Egyptians. Cabbage was introduced into European gardens in the ninth century and into the United States in the early days of colonization.

Cabbage belongs to the Cruciferae or mustard family. It is known by the technical name *Brassica oleracea* var. *capitata* Linn. The wild cabbage plant is herbaceous, usually perennial, but sometimes biennial. The cultivated cabbage is biennial, although grown as an annual crop. There is great variation among the cultivated types of cabbage. They differ in size, shape and color of the leaves, and in size, shape, color, and texture of the head.

Climatic Requirements.—Cabbage thrives best in a relatively cool, moist climate. The crop is grown in the South mainly during the winter and early spring. The main or late crop is grown almost entirely in the northern states, where the summer temperatures average relatively low.

The moisture supply during the growing season seems to be the most important factor governing the yield. Misner (1925) has shown that there is a close correlation between the July, August, and September rainfall and the yield of cabbage in New York State. On the average, a variation of 10 per cent in the rainfall for the 3 months resulted in a variation of 11 per cent in the yield per acre. Of course, there are exceptions to the general rule. For example, the total rainfall for the period might be normal, but for a part of the period it might be much below normal, in which case the yield probably would be low. Furthermore, a heavy rainfall may not be well distributed or much of the rain may run off. In either case there would not be close correlation between the rainfall and the yield.

Soil Preferences.—Cabbage is grown on all types of soils from the sands and mucks to the heavy soils. For a very early crop, sandy or sandy-loam soils are considered best, while for a late crop, where a large yield is the most important consideration, clay loams and silty soils are preferred. A good muck soil is very satisfactory for late cabbage. A sandy soil is excellent in the spring, when moisture does not become a limiting factor, but in late summer such a soil is not at all desirable. Early crops are grown mostly on light soils while the late crop is grown on heavy soils, which are most retentive of moisture and are richer.

Soil Reaction.—Cabbage does not grow well on a highly acid soil. Hester, Parker, and Zimmerley (1936) reported results on a Norfolk sandy-loam soil showing a marked increase in yield as acidity decreased from pH 4.3 to about pH 6.0. They state that maximum availability of phosphorus may be expected between pH 5.5 and pH 6.5 and since the phosphorus supply is important, they consider this reaction range as most satisfactory. Where clubroot is very serious, some authorities recommend application of caustic lime or hydrated lime to bring the soil to neutral, and then to add 1500 pounds more lime to control this disease. It should be pointed out that adding enough lime to make the soil neutral or alkaline in reaction may result in rendering some essential element unavailable. Under most conditions lime should be used on soil more acid than pH 5.5, but it does not seem desirable to decrease acidity beyond pH 6.5 except where clubroot is very serious and can be controlled by no other means.

Soil Preparation.—For early cabbage in the North, fall plowing is important since it is desirable to plant very early in the spring. In the South, cabbage is planted in the fall or winter depending on the locality and climate, therefore, summer or fall plowing is essential. Fall plowing in the North is desirable where sod land is to be used. The vegetable matter will then be partially decayed by spring and the soil in good condition to receive the crop.

For a late crop the preparation should be made with the idea of conserving all the moisture possible. Spring plowing is desirable in this case and the land should be harrowed at intervals to keep down weeds.

Manures and Fertilizers.—Cabbage is a gross feeder, especially of nitrogen and potassium. It is considered a hard crop on the soil and there is experimental evidence to substantiate this belief. Farmers often report that corn following cabbage produces a smaller yield than when it follows corn.

While manure is valuable, experiments indicate that soil-improving crops and commercial fertilizers can be substituted for manure with satisfactory results. Results of experiments on a silt-loam soil at the Rhode Island Station, reported by Crandall and Odland (1932), show that 8 tons of manure increased the yield significantly over the no-manure treatment. Soil-improving crops were grown on both manured and unmanured plots. The combination of 8 tons of manure and soil-improving crops with 1500 pounds of an 8–10–6 fertilizer produced nearly as large yields as 16 tons of manure and the same application of fertilizer. The plots on which the heavier application of manure was used produced two vegetable crops each year, while those plots given the 8-ton application produced one vegetable crop and a soil-improving crop each year. The quantity of nitrogen used, 120 pounds to the acre, is greater than can generally be justified where manure is used in considerable quantity.

Late cabbage, grown in rotation with general farm crops on clay loams and silt loams that are well manured, may require only phosphorus and 500 to 600 pounds of 20 per cent superphosphate should be sufficient. When no manure is used a complete fertilizer high in phosphorus, such as a 5–20–5 at the rate of 500 to 750 pounds to the acre, is suggested. Large expenditure for fertilizer for late cabbage seldom is justified on account of the relatively low returns per ton and per acre.

Experiments at Marietta, Ohio, on soil that varies from loam to fine sandy loam, as reported by Gourley and Magruder (1924) and by Comin and Bushnell (1928), have given results somewhat comparable to the Rhode Island results. In Ohio a complete fertilizer produced larger yields and greater profits than 16 tons of manure alone, or manure plus 400 and 800 pounds of 16 per cent superphosphate. Nitrate of soda added to the manure plots increased the yield over manure alone. In these experiments 75 pounds of nitrogen in a complete fertilizer produced larger yields than less nitrogen and 400 pounds of 16 per cent superphosphate gave as good results as a larger quantity. Potash had no significant effect on the yield of cabbage.

Considering the results of the above experiments, as well as various others, it seems evident that production can be maintained without manure. The humus supply must be maintained and on high-priced land it may be more economical to buy manure than to grow soil-improving crops. Where manure is used, 15 tons should be sufficient and this should be supplemented with phosphorus and some readily available nitrogen. When cabbage is grown as an early crop on sandy-loam soil without manure, a fertilizer supplying 75 to 100 pounds of each of the three important ingredients can be used to advantage.

Growing Plants.—There are several distinct methods of growing cabbage plants for the early crop: (1) sowing seed outside in the fall in the South, (2) sowing seed in the cold frame late in the fall or early winter and transplanting to the field direct from the seedbed, (3) sowing seed in a hotbed early in the spring and transplanting direct from the seedbed, (4) sowing seed in the greenhouse or hotbed and transplanting the plants at least once before setting them in the open.

In many sections of the South, especially along the Atlantic coast, from the eastern shore of Maryland south to Florida and along the Gulf Coast, the most common practice is to sow seed in open beds in late summer, or in the fall, and to set the plants in the field in 6 to 10 weeks. On the eastern shore of Maryland the seed is sown the latter part of August or early in September so as to have plants large enough to put out before cold weather sets in. In the coast section of South Carolina, the seed is sown early in October. In cooler sections of the South and in regions where there are great variations in temperature, seed often is sown in cold frames in late fall and early winter, and the plants set out in February.

Sowing seed in the hotbed in March and setting the plants direct to the field without transplanting is practiced to some extent in the North, but this method is not satisfactory where earliness is of prime consideration. Plants grown in this way are usually not well hardened, and therefore will not withstand freezing. Those that survive are likely to be weak and spindling.

The most common method for growing early plants in the North is to sow the seed in a greenhouse or hotbed in January or February and to transplant the seedlings, spacing them 1½ to 2 inches apart each way. Some growers transplant cabbage plants twice before setting them in the field, giving them more space at the second transplanting. If more space could be given at the first transplanting better results would be secured without additional transplanting.

Cabbage plants for the late crop in the North are grown in the open. The seed is sown about 6 to 8 weeks before time for planting in the field. A good, loose soil should be selected for the seedbed, which should be thoroughly prepared. Heavy fertilization of the seedbed is not desirable since a rich soil is likely to produce too rapid growth. Where the cabbage maggot is present the bed should be screened, or the plants treated with a solution of corrosive sublimate two to four times while still in the seedbed.

The quantity of seed required for an acre of land depends on the viability of the seed, the care taken in preparing the seedbed and the method of growing plants. If the seedbed is well prepared and given good care, more plants will be available from a given quantity of seed than if the soil is not well prepared and poor care is given. A pound of seed of high viability will furnish ample plants for 4 acres of land, if they are grown in greenhouses or hotbeds and the seedlings are "pricked out." When seed is sown in outdoor beds and the plants are transplanted direct to the field, it is not safe to expect more than enough plants for 2 acres from 1 pound of seed. Many of the plants are thrown away because they do not develop properly due to crowding in the seedbed.

Planting.—Cabbage plants, which have been well hardened, will withstand a temperature of 10° to 15° below freezing if not of long duration. In regions where the temperature seldom goes much below 32°F. it is safe to set cabbage plants in the fall or early winter. In the North well-hardened plants may be set out as early in the spring as the ground can be prepared or as soon as the danger of hard freezes is over. Late cabbage in the North is set out the latter half of June and in July depending on the earliness of fall freezes. About 4 months should be allowed late cabbage to mature.

The spacing of the plants depends largely on the variety. Small-growing varieties like Jersey Wakefield are set 12 to 15 inches apart in the row with the rows 2 to 3 feet apart. Larger varieties like Succession, Early Summer, and Copenhagen Market are set 18 by 28 to 18 by 36 inches. Very large cabbages such as Flat Dutch require more room and the plants are set at least 2 feet apart in the row, with the rows 3 to 3½ feet apart. Myers' (1916) results in Pennsylvania seem to indicate that close planting increases the total yield, but delays maturity and decreases the sizes of the heads of Jersey Wakefield, Early Spring, and Copenhagen Market varieties. However, the results were not entirely consistent and, therefore, should be considered as giving only an indication of what may be expected. The best plan seems to be to plant rather close in the row and to allow a liberal space between the rows for convenience in cultivating.

During recent years the market has preferred small heads of cabbage and objection has been raised to the large size of Danish Ballhead grown in New York State. The size can be regulated by spacing the plants. Where the demand is for small or medium-sized heads the spacing in the row should not be greater than 18 inches; 15 inches might be better. The yield per acre would be increased by close spacing under ordinary conditions.

Cabbage plants are set by hand and by means of transplanting machines. By the hand method the opening for the plant may be made by use of a dibble, trowel, or by means of a small plow. When the plow is used, the plants should be set immediately before the soil dries out. Hand transplanters are also used. These have attachments so that water may be applied around the roots as the plant is set. Machine transplanters are used to a large extent where considerable areas are planted. These machines do better work than is usually done by hand. They open the furrow, apply water around the roots, and pack the soil around the plant, all at one operation.

When setting out cabbage plants from the seedbed during the summer only the strong, stocky plants should be used because many of the weak ones do not withstand the shock of transplanting and many others make a slow growth. In an experiment in Pennsylvania, plants were graded according to size at the time of planting to the field. The experiment covered 3 years, 2 years with Enkhuizen Glory and 1 year with Danish Ballhead. The average of the yields from the different grades was as follows: small plants 12.7 tons per acre, medium 17.7 tons, ungraded 18.5 tons, and large 21 tons per acre.

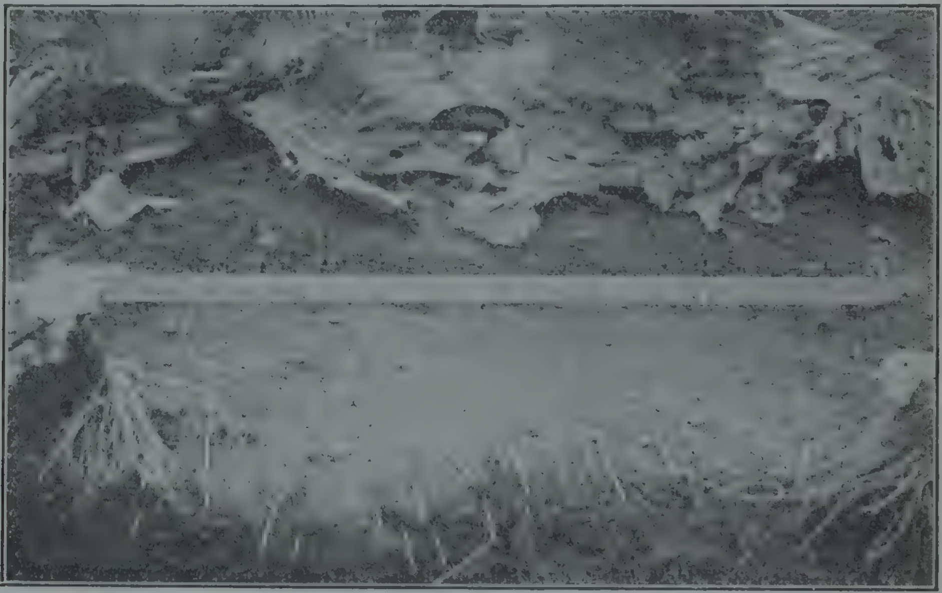

Fig. 33.—Roots of cabbage plants uncovered by washing off the surface soil to the depth of 2 inches. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Cultivation.—In the cultivation of cabbage great care should be exercised to prevent destruction of the roots; therefore only very shallow cultivation should be given after the plants have attained considerable size. Many of the roots of the cabbage plant grow within 2 inches of the surface of the soil and these run almost horizontally (Fig. 33). Before the plant is half grown the roots cross in the centers between the rows, and if deep cultivation is given more harm than good may be done. Sufficient cultivation should be given to keep down weeds and probably to maintain a soil mulch while the plants are small. After the plants are half grown, cultivation is not so important unless weeds are troublesome. Cultivation should cease when it is impossible to perform the operation without injuring the plants, since there is evidence that little moisture is lost from the soil by evaporation from the surface, when the plants are large. There is also evidence that cultivation destroys the roots near the surface.

Experimental evidence obtained at Ithaca, N. Y., indicates that on a sandy-loam soil the soil mulch is not of great importance. The average yield for the 6 years was the same on the scraped plots as on the cultivated plots and the only difference between these treatments was in the presence and absence of a soil mulch. Weeds were kept down in both cases. A soil mulch was maintained on the cultivated plots throughout the growth of the crop. On a heavier soil the mulch might be of greater value, but even under such conditions, root destruction by deep cultivation may offset any benefit derived from the mulch.

When the plants are small, cultivation may be done by gang cultivators or by any ordinary shovel cultivator, but when the plants get larger only light cultivators should be used. A harrowlike cultivator, or one of the Planet Junior 15-tooth type, may be used to good advantage after the plants are well established. In fact if the ground has been well prepared, the light cultivator is best for all cultivation.

Hand hoeing or hand weeding is usually necessary to keep the weeds down between the plants in the row. This is especially important in the spring when weed growth is rapid.

Types and Varieties.—Seedsmen list a large number of varieties of cabbage but only a few of them are of much importance. Myers and Gardner (1919) report that, in 1915, 54 representative seedsmen listed 243 varieties, but of these only 35 were listed by more than 10 seedsmen and 174 varieties were listed by not more than two seedsmen.

The different varieties grown in the United States have been classified in various ways. No classification that has been attempted is entirely satisfactory, but the one suggested by Myers (1915) is probably the best. This is similar to the one suggested by Allen[1] but three groups are added to those mentioned by Allen. Myers suggests eight groups as follows:

1. The Wakefield and Winningstadt group.
2. The Copenhagen Market group.
3. The Flat Dutch or Drumhead group.
4. The Savoy group.

[1] "Cabbage, Cauliflower and Allied Vegetables," p. 54. Orange Judd Co.

5. The Danish Ballhead group.
6. The Alpha group.
7. The Volga group.
8. The Red Cabbage group.

The Wakefield and Winningstadt group includes varieties having small pointed heads (Fig. 34). The plants mature early and are grown chiefly for the early crop. The best known varieties of this group are Jersey Wakefield, Charleston Wakefield, and Early Winningstadt. Early Winningstadt is a good home-garden variety but is not grown to any great extent in the United States, except in southern California where it is important.

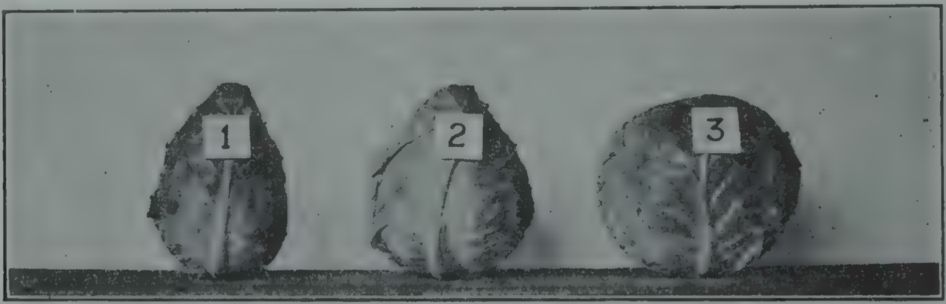

Fig. 34.—Three varieties of early cabbage: 1, Jersey Wakefield; 2, Charleston Wakefield; 3, Copenhagen Market.

The Copenhagen Market group is important largely because of the variety Copenhagen Market (No. 3, Fig. 34), which is the most important early, roundhead cabbage grown in the United States. It is nearly as early as the Jersey Wakefield and the heads are much larger. The head is round and compact, having few outer leaves and a small core. The leaves are small to medium in size, light green in color, and covered with a heavy bloom. The stem is short. This is one of the most important early varieties in the North and is also used for midseason and early fall crops. The Golden Acre, an early strain of Copenhagen Market, has become popular during recent years. It produces a smaller head than most strains of Copenhagen Market.

The Flat Dutch group is distinguished from all others by the flat heads (Nos. 5 and 6, Fig. 35). The plant is medium to large; the outer leaves are large and numerous, curving inward and enclosing the head loosely. The color is light green. The heads are large, flat, and fairly solid. The leaves forming the head fold over each other at the center. Varieties in this group differ considerably in the length of time required to mature.

The Savoy group is characterized by foliage very much blistered or wrinkled. The foliage is dark green and has very little bloom. The quality of this group is considered superior to all others, but it is not of much commercial importance although long cultivated. The most important varieties are Savoy, Drumhead Savoy, and Perfection Savoy.

The Danish Ballhead group contains the most important varieties of cabbage, the best known being the Danish Ballhead, also known as Hollander, Danish, Danish Roundhead, and many other names. The mature plant is of medium size; the outer leaves are few in number, curve inward to some extent, are light green in color and covered with a fairly heavy bloom. The head leaves are of fine texture and reach well past the center. The head is of medium size and very solid. It is the best keeping variety grown in the United States and is used to a greater extent than all other varieties of late cabbage.

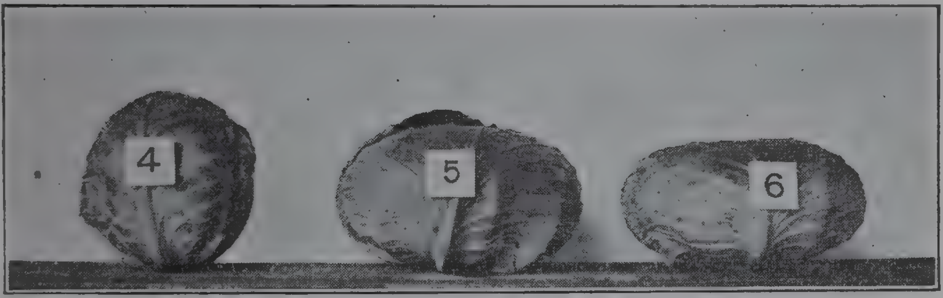

FIG. 35.—Three varieties of midseason cabbage: 4, Enkhuizen Glory; 5, Early Summer; 6, Succession.

The Alpha group contains the earliest varieties. The heads are smaller than Wakefield, round, and very solid. The plants are small and may be planted close together. The group is of little commercial importance, and no well-known varieties are included in it. Miniature Marrow and St. John Day are perhaps the best known.

The Volga group is best represented by the variety Volga. The mature plant is large and has few outer leaves, which curve outward; the leaves are large and thick and steel-blue in color. The head is of medium size, globular but somewhat flattened; the head leaves extend a short distance past the center thus giving it a bald appearance. The head is solid on top but rather open below.

The Red Cabbage group is distinguished from all others by its deep purplish-red color. Otherwise the plants show considerable resemblance to the Danish Ballhead but the yield is usually smaller. The best known red varieties are Red Rock or Mammoth Red Rock, Red Dutch, and Red Danish or Danish Red. These are probably different strains of the same variety.

Premature Seeding in Cabbage.—Growers of early cabbage frequently suffer financial losses due to the development of the flower stalks before the plants head. In some sections of the South, the plants are set in the field in the fall and the crop is put on the market in spring or early summer. Under these conditions, the plants are in the field throughout the winter and in some seasons a considerable percentage shoot to seed. In the North premature seeding is not uncommon, especially when the plants are started early and grown at relatively low temperatures for several weeks. Various factors have been mentioned as possible causes of bolting, including (1) early sowing of the seed, (2) warm, open winters. (3) cold winters, (4) extreme changes in temperature, (5) checking growth of the plants in the plant bed, (6) poor seed, especially seed of low vitality, (7) poor soil, (8) influence of heredity, and (9) various cultural practices that affect the rate of growth.

Results of studies made by Miller (1929) and by Boswell (1929) indicate clearly that growing the plants at relatively low temperature is associated with premature seeding. This exposure to relatively low temperature seems to be essential to flower-stalk formation, but other factors have considerable influence on it. Both Boswell and Miller found that the size of the plant at the time it is exposed to low temperature is of considerable importance. The larger the plants are (other factors being the same) at the time growth is checked by low temperature, the greater is the tendency for wintered-over cabbage to shoot to seed in the spring. Boswell found that the percentage of seeders increases with increasing size of plants above a stem diameter of 6 millimeters. The earlier the seed is sown, the higher is the percentage of seeders, due mainly to the fact that the early plants are larger than the others at the time of exposure to low temperature. Increasing the size of the plant by fertilizing the plant beds increases the percentage of seeders, but Boswell found that the fertilizer treatment in the field had no effect on flowering. This is due probably to the fact that the plants are set in the field so late in the fall that the fertilizer has little or no effect on growth before winter.

Strains exhibit significant differences in tendency to shoot to seed, even when grown under identical conditions. Zimmerley (1922) found that the strains of Wakefield varieties which produce small, compact heads and head uniformly, are less likely to shoot to seed than are those that are somewhat openheaded, leafy, and later maturing. This indicates that shooting to seed is hereditary, but experimental results show clearly that environmental conditions determine the expression of the hereditary tendencies.

Seeding of Mature Cabbage.—The effect of temperature on reproduction in cabbage is well illustrated in results of experiments with mature plants conducted by Miller (1929). Mature plants taken up in the fall before they were subjected to low temperature did not seed when grown subsequently in a warm greenhouse (60° to 70°F.), while those grown in a cool greenhouse (50° to 60°F.) produced flowers and seed. The plants grown continuously in the warm house produced three heads in succession during the first year (Fig. 36). One of these plants was kept in the warm house for 2 years after it was brought in from the field in October, 1925, and this plant produced six heads. After the sixth head had developed and the plant was about 3 years old it was moved to a cool greenhouse and within a few months it flowered as is shown in Fig. 37. The plants used in this experiment represent a pure-line strain so that all of them had the same genetic constitution. The difference in behavior of the plants grown under the two ranges of temperatures could not have been due to hereditary differences, but to the environment.

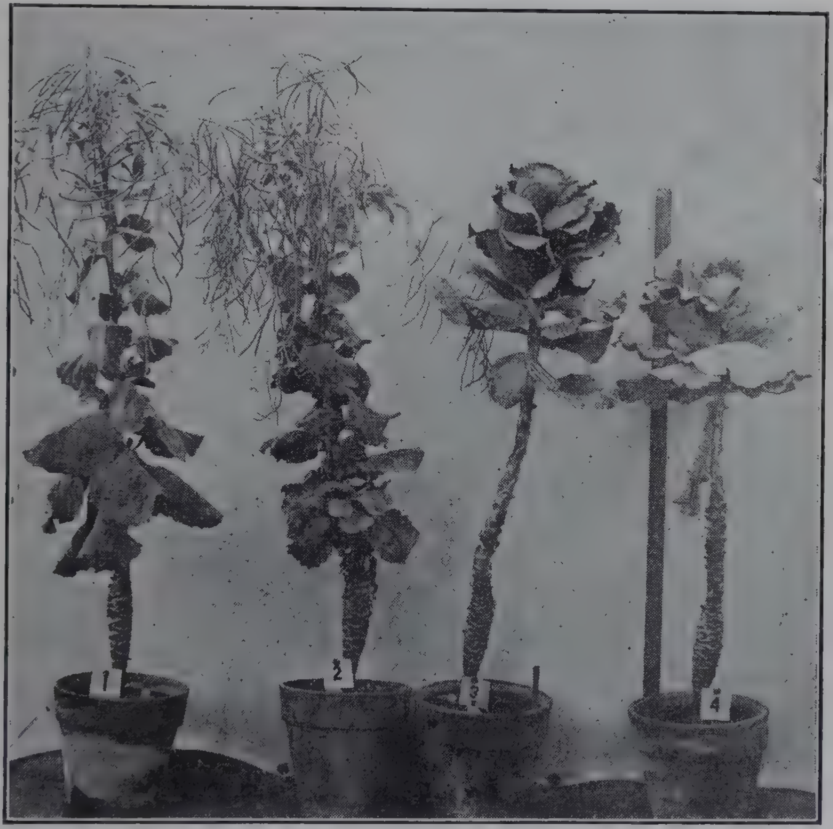

Fig. 36.—Effect of a rest period on seeding of mature cabbage when grown in a warm greenhouse. Plants 1 and 2 were given a rest period in storage for 2 months; plants 3 and 4 were brought directly from the field to the greenhouse. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

After being stored at 40°F. for 2 months, the plants flowered in the warm greenhouse a month earlier than similar plants grown in the cool house. Storage at 40°F. for 2 months hastened flowering in the cool greenhouse. Storage for 15 and 30 days had little effect on flowering. Chemical analyses of the tissues surrounding the growing point indicate a marked increase in the quantity of elaborated foods in this region. It seems probable that this increase is associated with the development of the flower stalk.

Increasing the length of day by use of electric lights had little or no effect on flowering. Etherizing the plants had no effect on time of flowering.

The results of these studies show that the type of growth can be controlled by temperature and that it is a relatively simple matter to produce one generation of plants each year. In one experiment 10 plants produced two crops of seed and two crops of heads in 2 years, but the normal order was reversed. In improvement work it is feasible to grow heads to maturity in the field during the summer and to produce seed in the greenhouse during the winter. The quickest method seems to be to store the plants for about 2 months at a temperature around 40°F. and then to grow them in a warm greenhouse (60° to 70°F.).

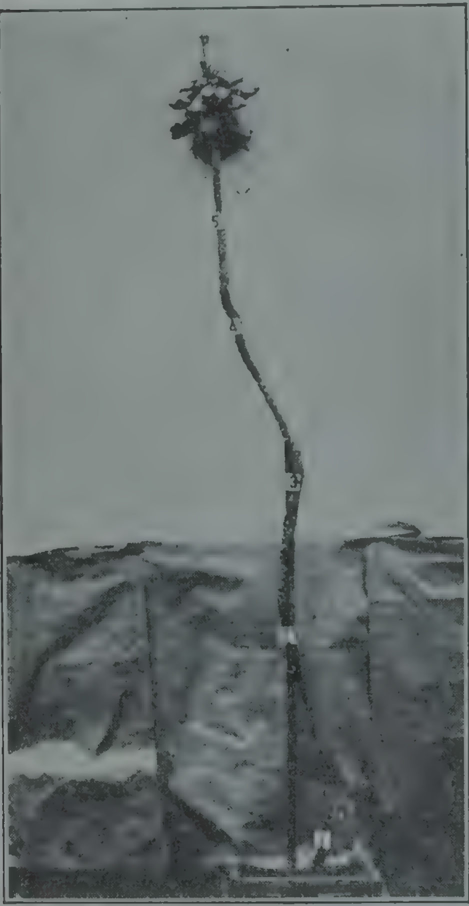

Fig. 37.—Effect of temperature on seeding of mature cabbage. This plant was grown in a warm greenhouse for 2 years and produced six heads at points 1, 2, 3, 4, 5, and 6; it was then transferred to a cool greenhouse and within a few months it flowered. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Diseases.—There are several very serious diseases of cabbage, the most important being clubroot, rootknot (nematodes), yellows, blackleg, and black rot. A serious infection of some of these is sufficient to make cabbage growing unprofitable, and in many instances results in total loss of the crop.

Clubroot (*Plasmodiophora brassicae* Wor.) is produced by the invasion of a slime mold on the roots. Plants affected by this disease show, in the earlier stages of growth, a wilting of the foliage on sunny days, with recovery toward evening or on cloudy days. The roots of affected plants show characteristic swellings, which often become very large. The mass of thickened malformed roots presents a clubbed appearance.

The organism is a soil parasite which thrives best in an acid soil. Corrosive sublimate solution (1 ounce to 10 gallons of water) applied around the roots of the plants in the seedbed will hinder clubroot infection. Several applications may be necessary, but this same treatment will control the cabbage maggot. A long rotation, in which no cruciferous plants are grown, is of value in controlling the disease in the field.

The only other feasible method is by controlling the soil reaction by liming as discussed under "Soil Reaction." The lime for clubroot control should be applied in the spring rather than during the previous fall.

Root Knot.—This is a disease caused by a parasitic eelworm (*Heterodera radicicola* (Greef) Mull.). The parasite penetrates the roots and causes irregular swellings, which are sometimes confused with clubroot. Root knot as a rule is characterized by smaller swellings than clubroot. More of the feeding roots are affected and the knots are located nearer the tips of the roots. Root knot is not serious in the North but is very destructive to nearly all kinds of crops in the South.

Crop rotation is the most effective means of controlling this disease, but in order to starve out the parasite the alternating crops should be immune or resistant to root knot. A rotation of at least 3 years, accompanied by clean cultivation, should be practiced. Harter and Jones (1918) state that there are 480 different species of plants known to be susceptible to root knot, including many cultivated plants and numerous weeds. The following crops are listed by them as being immune or highly resisted to the disease, and can be used in the rotation; corn, winter oats, rye, timothy, pearl millet, sorghum, wheat, crab grass, the Iron and Brabham cowpeas, velvet beans, peanuts, and beggarweed. The following crops should be avoided in the rotation: alfalfa, vetch, soybeans (except Laredo), cowpeas (except Iron and Brabham), clover, tomatoes, cotton, okra, cucumbers, watermelons, cantaloupes, celery, beans, sweet potatoes, tobacco, potatoes, and all crucifers.

Yellows.—This disease is recognized in the field by the lifeless, yellowish-green color, which shows up in 2 to 4 weeks after transplanting. The plants are stunted and often warped and curled, due to the attack being more severe on one side of the plant than on the other. The vascular bundles of the stem and lower leaves become darkened, the color deepening as the disease progresses. Diseased plants shed their lower leaves while the plants are still attempting to grow.

This disease is caused by *Fusarium conglutinans* Woll. When the soil is seriously infested with the fungus a large part of the crop may be destroyed. The disease is most serious in the region extending from Wisconsin to Kansas on the west and eastward to Pennsylvania and Virginia. Tisdale (1923) has shown that the fungus does not develop at temperatures lower than 68°F. and that it reaches its maximum rate of growth when the temperatures reach 80° to 90°F. At 95°F. growth is inhibited.

Disinfection of the seed with mercuric chloride solution (1:1,000) reduces the danger of carrying the disease to new districts, but is of no practicable value if the crop is to be planted on infected soils. The germs persist indefinitely in the soil and therefore ordinary crop rotation does not control the disease. Seedbed infection is one of the worst dangers, hence, care should be taken to plant the seed in clean soil. Where the disease is present and is serious, the only practicable control measure is to grow resistant strains or varieties. There are resistant strains of the various important cabbage types: Jersey Queen developed from the Jersey Wakefield, and Iacope, Detroit Resistant, and Early Resistant Copenhagen Nos. 19 and 21 all early varieties developed from the Copenhagen Market. All Head Select, Wisconsin All Seasons, and Globe are later resistant, domestic varieties. Wisconsin Ballhead, Wisconsin Hollander, and Red Hollander are late varieties of Danish that are resistant to yellows. Other resistant strains are being introduced from time to time.

Blackleg.—This disease is caused by a fungus parasite (*Phoma lingam* (Tode) Desmax). It may invade almost any portion of the plant but the worst damage occurs when it kills the stems of the young plants in the seedbed or in the field. Infection often occurs on the stem near the ground, causing dark sunken areas. The disease spreads from these areas, gradually killing the base of the stem and roots, so that the plant wilts. The wilting of the entire plant is characteristic of the advanced stages of this disease, and the leaves adhere to the stem instead of falling off as in the yellows. In the advanced stage of the blackleg, the dead areas are covered with very small black specks, which are the fruiting bodies. These live in the soil on parts of diseased stems and leaves and may persist for 2 years or more. Clayton (1924) expressed the opinion that the major method of overwintering is on the seed, and that while the fungus lives in the soil for a year or two, it dies out completely in 3 years, providing no cruciferous plants are grown on the land during that period.

Crop rotation and seed treatment are the methods of control generally recommended. The rotation should cover at least 3 years. Treatment of the seed with corrosive sublimate solution 1:1,000 for 30 minutes will reduce the infection, but will not eliminate it entirely as it kills only the part of the parasite that is on the outside. Hot-water treatment, 122°F. for 25 to 30 minutes, is effective in destroying the parasite on the inside as well as on the outside. This is the most successful method, but must be used with great care since it is likely to reduce the germination of the seed, especially if the seed is weak. Before using this method a sample of the seed should be tested for germination; if the germination is slow and the percentage low, it is best not to treat it. By this method the seed is placed in small cotton bags and immersed in water kept at the temperature mentioned for 25 to 30 minutes. The water should be stirred constantly. When the time is up the seed should be taken out, immersed in cold water, and then spread out to dry.

Clayton (1924) found that treatment of the seedbed with corrosive sublimate for the cabbage maggot effectively controls blackleg. The plants are slightly weakened by this treatment. Cauliflower and Brussels sprout plants are distinctly weakened by it.

Black Rot.—This is caused by a bacterium (*Phytomonas campestre* (Pammel) Erw. Sm.) and appears in the plant at any stage of growth. The yellowing of affected leaves followed by a blackening of the veins is the first indication of the disease. Later the plants show a dwarfing or one-sided growth of the head, or, if the disease is severe and starts early in the season there may be no head formed. The heads sometimes rot and fall off. A cross section of the stem of affected plants shows a brown or black ring corresponding to the woody tissue. Often the blackening of the veins of the leaf can be seen through the outer tissues.

This disease is a serious pest of cabbage, cauliflower, Brussels sprouts, and rutabagas. Cauliflower is more susceptible than any of the other crops and on Long Island it is the most serious trouble that the cauliflower growers have to combat. While the bacteria probably live over winter in the soil, Clayton (1924) expressed the opinion that seed infection is a major means of overwintering, but that it may also live over in the stems of diseased cabbage and Brussels sprouts.

Seed treatment by the hot-water method described for blackleg destroys the bacteria on the seed. Treatment of the seedbed with corrosive sublimate solution for the control of the cabbage maggot gives good control of the black rot. The use of clean seed, crop rotation, and seedbed sanitation are recommended. The rotation should be one in which no cruciferous crops or cruciferous weeds are allowed to grow for 4 or 5 years.

Other Diseases.—Many other diseases attack cabbage, including alternaria leaf spot, wire stem, bacterial-leaf spot, sclerotinia rot, white rust, downy mildew, anthracnose, and several others. It is seldom that these cause serious losses, therefore, no discussion of them is given here.

Insects.—Cabbage and closely related plants are attacked by many insects including both those with chewing and those with sucking mouth parts. The important chewing insects of cabbage are the cabbage maggot, green cabbage worm, southern cabbage butterfly, cabbage looper, diamondback moth, cross-striped cabbage worm, cabbage webworm, garden webworm, purple-backed cabbage worm, and zebra caterpillar. The important sucking insects attacking cabbage are cabbage aphis, turnip aphis, and harlequin cabbage bug.

Cabbage Maggot (*Phorbia brassicae*).—The cabbage maggot is a small whitish larva of a black fly a little smaller than the common housefly. The fly deposits eggs just below the surface of the ground, on or near the roots of cruciferous plants. The eggs hatch in a few days and the larvae feed on the plants for about 3 weeks. They first attack the rootlets and then burrow into the main root, causing the plant to wilt and, in most cases, to die. Even if the plant is not killed outright its vitality is often so weakened that only a small head, or no head at all, is formed. In the North the maggots are most destructive to early cabbage in the field and late cabbage in the seedbed.

For the control of cabbage maggot on early cabbage in the field the most effective remedy now known is a solution of corrosive sublimate 1:1,000 or 1 ounce of the powder to 8 to 10 gallons of water. Two or three applications are made, the first one about the time the adult fly appears, which is usually soon after the plants are set. At each application about one-half cupful of the solution is applied around each plant.

For control of the cabbage maggot on the late crop, the common method has been to screen the seedbed with cheesecloth. This prevents the female from depositing the eggs in the seedbed, therefore the plants are free of maggots. In recent years soaking the soil of the seedbed with corrosive sublimate solution has given good results when three or four applications have been made. This method bids fair to replace the older method of screening the bed.

Green Cabbage Worm, or Imported Cabbage Worm (*Pieris rapae*).—This worm is the larva of a small white butterfly. The larva is about 1 inch long and velvet green in color. It is the most destructive of the common cabbage insects, eating holes in the leaves and often burrowing into the head.

Spraying or dusting with arsenicals will control this pest if the work is done well and at the proper time. With a spray it is desirable to use some material to make the liquid adhere to the foliage. If dust is used it is best to apply it while the foliage is wet. There is some danger in using arsenicals after the heads begin to form. Rotenone dusts containing one-half of one per cent rotenone are effective and safe. Use of lead arsenate dust up to time of head formation and rotenone dust after the heads begin to form would seem to be a good procedure.

Southern Cabbage Worm (*Pontia protodice*).—In the adult stage, this insect resembles the adult of the green cabbage worm, but is pure white in color. The larva is strongly colored, purplish and yellow striped, with black spots. The injury done by this insect is identical with that of the green cabbage worm, therefore the same control measures are used

Cabbage Looper (*Autographa brassicae*), the larva of a moth, resembling the cutworm moth, feeds on the foliage of cabbage and related plants. This worm can be distinguished from the others by its peculiar looping or doubling up as it crawls. It is more active than the other worms previously considered and is, therefore, more difficult to control. In addition to attacking all cole crops it sometimes injures peas, beets, celery, and lettuce. Rotenone is not very effective in controlling this insect. Spraying or dusting with arsenicals, before the head begins to form, and using pyrethrum dusts after the heads begin to develop are the measures recommended. If pyrethrum extract is used, the dust should contain at least 0.3 per cent pyrethrins. If a dust is made from the ground flowers a sufficient quantity should be used to give 0.6 per cent of actual pyrethrins.

Other Cabbage Worms, including the diamondback moth, cross-striped cabbage worm, cabbage webworm, purple-backed cabbage worm, and zebra caterpillar, injure the crop in much the same way as those already discussed and are controlled by the same measures. The cross-striped cabbage worm bores into the head in the same manner as the green cabbage worm.

Cabbage Aphis (*Aphis brassicae*).—This is one of the species of insects commonly called plant lice. These insects are more injurious during the latter part of the season than earlier. The cabbage aphis is covered with a coat of fine waxy powder, very much like the bloom on cabbage leaves. This covering protects the insects from spray material since the liquid runs off of their waxy surface. Spraying with nicotine sulphate solution, to which soap has been added as a sticker, has been recommended in the past. Experiments have shown that dusting with nicotine preparations gives good results. The treatments for the cabbage aphis and for cabbage worms can be combined. When dust is used, one containing 5 pounds of nicotine sulphate, 10 to 15 pounds of powdered lead arsenate or calcium arsenate, and 80 or 85 pounds of hydrated lime is satisfactory.

Turnip Aphis (*Aphis pseudobrassicae*) is closely related and similar in appearance to the cabbage aphis. The character of damage, life history, and means of control are the same as for the cabbage aphis.

Harlequin Cabbage Bug (*Murgantia histrionica*) is a true bug about ⅖ inch long, mottled red, black, or yellow. Both the adult and the young suck the juices and inject a poison into the plant. In many sections of the South, this insect is one of the most important pests. The young insects are much more easily killed than the adults, but both young and old are difficult to kill by ordinary sprays and dusts. Spraying with nicotine sulphate and kerosene emulsion is partially effective if applied while the insects are young. Other remedies are clean culture, especially in the fall, trap crops of mustard or other crops in the spring, and hand picking. All stumps and refuse of the crop should be destroyed in the fall so as to reduce hibernating shelter as much as possible. A few piles of rubbish left in the field in the fall will act as traps. After the bugs have collected, the piles should be burned. A trap crop of mustard will attract the bugs and they will collect on it. When the trap crop becomes infested it may be sprayed with kerosene or strong kerosene emulsion.

Harvesting.—Cabbage which is grown for the early market is harvested as soon as it has attained sufficient size to be placed on the market, since earliness is usually of more importance than size. The first shipments from the South usually consist of small, immature heads, but as the season advances the quality improves and the heads are closely trimmed. Midseason and late cabbage is not harvested until the heads are full and hard.

In harvesting, the heads are cut with a large knife or, in some cases, with a hatchet. The head is grasped in one hand and the plant is bent over so that the head can be cut above the outer leaves. Quite commonly the cutter takes two rows at a time, and as he cuts the heads he places them on the row to be gathered by others or he tosses them to a man on a wagon or truck. For late cabbage, care is taken to prevent bruising the heads; for this reason the cutter usually places them on the row to be gathered by others, who toss them to a man on the wagon or truck. They are carefully placed and are hauled to the car or to the storage house.

Grading and Packing.—Only a small part of the cabbage crop is graded according to official grades. The common practice in many regions is to discard low-grade heads and to include the remainder in one grade without designating the grade name or number. In many cases, when a grade is designated, it does not conform to any official standard. Since the U. S. Department of Agriculture has worked out standards which have been adopted by many states, it would seem advantageous to use these standards when grading cabbage for market. The grade specifications are changed from time to time and for this reason they are not given here.

Most of the late crop of cabbage grown in the North is shipped in bulk, although there is increasing use of sacks holding 50 pounds. Cabbage grown in the South and West for distant markets is packed in containers of various kinds and sizes, but special crates are replacing other types of packages. A large number of different shapes and sizes of crates are used. Spillman and Davis (1929) suggested the following five sizes that they thought would meet the needs:

	Inside dimensions, in.	Length of slat, in.
Florida type	12 by 18 by 33	36
Norfolk type	12 by 18 by 33	37⅜
Mississippi Valley type	16 by 16 by 27½	30
Colorado type	22 by 18¼ by 24	25¾
Pacific coast type	22½ by 24 by 20¾	24

Reducing the number of kinds and sizes of crates would result in economy of manufacture and eliminate a great deal of the confusion that now exists.

Storing.—A large part of the late crop of cabbage grown in the North is stored for winter use. Outdoor storage is used for cabbage grown for home use and to some extent for the market crop, but a large part of the commercial crop is stored in special storage houses.

The essentials of success for keeping cabbage in storage are (1) a good storage variety, (2) freedom from disease, and injury of any kind, (3) a relatively uniform temperature near the freezing point, and (4) a moderate degree of humidity, enough to prevent wilting but not so moist as to cause condensation.

A good storage variety of cabbage is one with compact, hard heads such as the Danish Ballhead.

Heads that are diseased when harvested will not keep so well in storage as those that are free from disease. Even if the particular disease present does not continue to develop in storage the diseased areas give a good opening for some of the storage rots. For the same reason mechanical injury caused by rough handling is likely to increase loss and shorten the storage period.

The lower the temperature the longer cabbage will keep, provided the heads do not actually freeze. In fact, slight freezing does not cause serious injury. Since cabbage will not freeze in a room where the air temperature is 32°F., it is safe to maintain that temperature.

Moderate humidity in the storage house is important since the common storage rots develop rapidly in a very moist atmosphere, and wilting occurs under very dry conditions. In many storage houses the greatest problem is to control the humidity. In some houses a drying agent such as calcium chloride is used to take up the moisture.

Various methods of outdoor storage are employed for keeping cabbage for home use, and for market for relatively short periods. The heads are sometimes stored in conical pits in much the same manner as root crops. Another common method is to pull the plants, roots and all, and place them in a pit with their heads down. In Maryland and Virginia, a common method is to pull the plants and set them side by side with the roots down in a shallow trench, the length of which corresponds to the width of the bed. The bed may be any width up to 8 or 10 feet and as long as necessary to hold the number of cabbages to be stored. After the first trench is filled with cabbage, a furrow is thrown against the roots and stalks and the dirt packed around them nearly up to the heads. A second row is set in the bottom of the second furrow or trench and the operation repeated until all the plants are stored. Around the bed a frame of boards or poles is erected about 2 feet high. The outside is banked with earth and the top is covered with straw, hay, or corn stover placed on poles laid across the bed. Provision should be made for access to the bed to remove the cabbage as needed. The heads are cut off and the roots left in position. In the spring the stalks produce sprouts which are prized as greens.

It is impossible completely to control the temperature and humidity in any type of outdoor storage; in addition it is very inconvenient to remove the cabbage when wanted. For these reasons most commercial cabbage is stored in specially constructed warehouses. These are built aboveground and are usually low. The house should be well built to prevent rapid changes of temperature on the inside.

The walls of the house, if of brick, have two tiers with an air space between, and when made of wood three layers of boards and two or more layers of heavy paper. Two air spaces 4 to 6 inches wide are left in the walls. The ceiling or roof is well insulated, there being usually two layers of boards and two layers of heavy paper with an air space between the outer and inner layers.

Ventilation is provided by means of openings through the walls near the ground and ventilators through the roof. In a wood-frame house, 35 by 77 by 25 feet, at Apulia, N. Y., there are eight openings 1 by 1 foot near the floor and eight windows 2 by 3 feet near the top of the walls. Seven ventilators 1 foot in diameter extend through the roof. There are two large double doors, one at each end of the house. All openings are constructed in such a way that they can be made nearly airtight.

Large storage houses usually have passage ways through the center sufficiently wide to admit a wagon or truck for convenience in loading and unloading. The heads of cabbage are placed in narrow bins or on shelves as shown in Fig. 38. Where bins are used they should be narrow, preferably not over 4 feet, and the depth should not exceed 6 or 7 feet. The length from front to back may be 18 to 20 feet. In some houses, bins are placed one above the other; this is satisfactory if provision is made to take care of drip from the upper bins. Shelves are better than bins but they are more expensive and take more space.

The shelves may be made for one, two, or more layers of heads. With either bins or shelves there should be air spaces between them and the walls of the house, also under them and between the rows of bins or shelves. Bins are usually made by nailing slats to both sides of 2- by 4-inch uprights so that there is a 4-inch air space between bins. The slats are placed at least 1 inch apart. The floor of the bins should be raised at least 4 inches from the floor and the boards or slats should be separated so as to allow air to circulate up through the heads of cabbage.

Cabbage shrinks considerably in storage and this should be taken into consideration in estimating the cost of storing the crop. Misner (1925) reported shrinkage and other losses in a cabbage storage house at Little York, N. Y. These figures are based on the total quantity of cabbage put into and taken out of the storage house for the years 1907 to 1921. The quantity stored varied from 348 to 556 tons and the shrinkage and losses, calculated on the basis of quantity stored, were from 7.4 to 27.6 per cent, with an average of 15.9 per cent. The shrinkage of cabbage put in house storage depends chiefly on the number of days stored and the temperature during storage. The longer the period and the higher the temperature, the greater is the shrinkage. Of course, disease and insect and mechanical injury affect the keeping of cabbage in storage, but in general only reasonably good cabbage is put in storage to be kept for any considerable period. For this reason, Misner found that there was a fairly close correlation between length of storage and total shrinkage of cabbage.

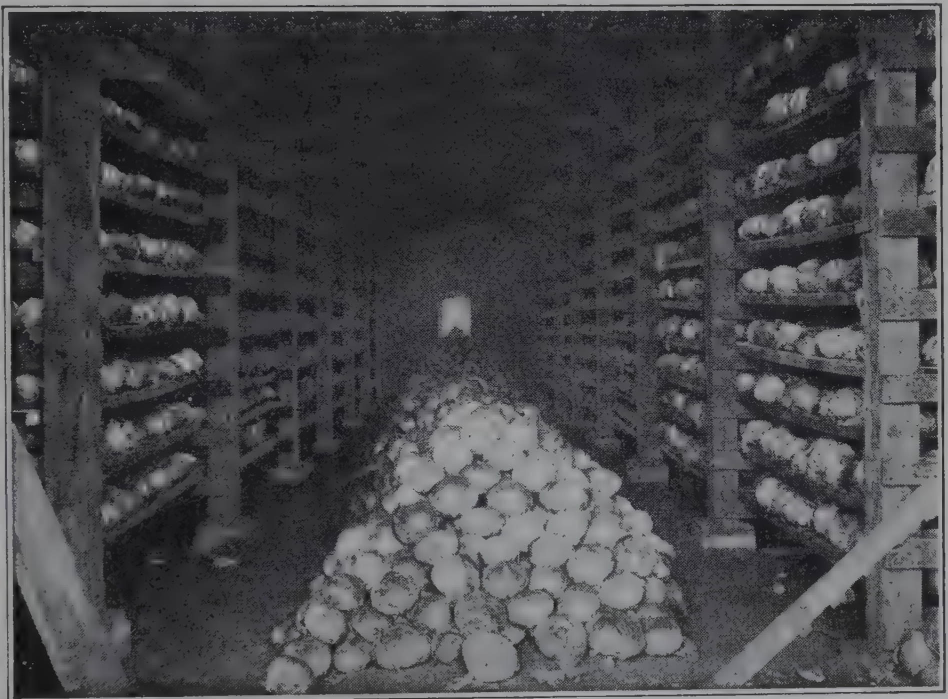

FIG. 38.—Interior of a cabbage storage house, showing driveway through center and heads of cabbage placed on slatted shelves on both sides of the driveway. (*Courtesy of U. S. Dept. Agr.*)

CAULIFLOWER

Cauliflower is grown for its white, tender head or "curd" formed by the shortened flower parts. While the crop is grown in much the same way as cabbage, it is much more difficult to grow cauliflower successfully than it is to produce cabbage.

Statistics of Production.—Cauliflower is not one of the most important of the vegetable crops, ranking fifteenth or sixteenth in the list from the standpoint of total value. While statistics are available for the important producing states only, these supply a large part of the entire crop and show the trend in production and price. Table XXXI gives the estimated acreage, production, and value of the crop in the important states for the years 1918 to 1937.

TABLE XXXI.—AVERAGE ANNUAL ACREAGE, PRODUCTION, AND FARM VALUE OF CAULIFLOWER GROWN IN THE UNITED STATES BY 5-YEAR PERIODS 1918 TO 1937

Year	Acreage	Yield per acre	Production (000 omitted)	Price per crate	Value (000 omitted)
1918–1922	8,012	272 crates	2,179 crates	$1.47	$3,205
1923–1927	16,154	241 crates	3,893 crates	1.25	4,876
1928–1932	27,450	243 crates	6,658 crates	.80	5,294
1933–1937	29,468	246 crates	7,238 crates	.74	5,347

The figures in Table XXXI show that the average annual acreage of cauliflower was over three and one-half times as great in the period 1933 to 1937 as in the 1918 to 1922 period. The price received per crate declined markedly during this period; this is explained by the large increase in production and the change in economic conditions. The lowest price received during the period was in 1934 when the average was 59 cents per crate. Other low-price years were 1933, 1932, 1935 and 1931 in the order given. The effect of the depression on the price of cauliflower is well shown by comparing prices in the years 1932–1935 with those in 1936 and 1937. The crop in 1936 and 1937 was considerably larger than in any year from 1932 to 1935, whereas the price averaged 85 and 86 cents per crate respectively in 1936 and 1937 and only 63, 61, 59, and 72 cents respectively in the years 1932 to 1935. In 1937, California produced over one-half of the cauliflower acreage with 16,000 acres; New York was second with 6,400 acres; Colorado third with 2,720; New Jersey fourth with 1,600 acres; Washington fifth with 1,100 acres; and Oregon sixth with 900 acres although about 300 acres of spring cauliflower was killed by a freeze in Oregon in January.

Climatic Requirements.—Cauliflower thrives best in a cool, moist climate. It will not withstand so low temperature or so much heat as will cabbage. Cauliflower heads will not develop well in hot weather, and for this reason, it is grown mostly in the fall and winter. Few sections of the United States have the combination of climatic conditions that is favorable for its production. Sections of California have favorable conditions during the fall and winter. Two sections of New York, Long Island and Erie County, have relatively long cool autumns, because of the tempering influence of near-by bodies of water—the Atlantic Ocean and Lake Erie. A third section of New York, the Catskill Mountain region, has a relatively cool summer season and a good rainfall during this period so that cauliflower can be grown successfully during the summer. Early fall freezes prevent successful cauliflower production as a fall crop in the Catskill section. Most of the California crop is harvested from the first of November to the last of March. The Oregon crop is harvested mainly in October, November, February, and March. New York cauliflower is harvested mainly from the first of August to the last of November.

Soil and Soil Preparation.—When other conditions are favorable, cauliflower can be grown on any good soil, but a fairly deep, loamy soil is desired. Sandy loams and silt loams are preferred although good clay loams are used. The soil should be well supplied with organic matter and be well drained. Good drainage is particularly important where the crop is grown during the fall or in the winter.

Thorough preparation of the soil is important. Where the crop is planted in the field in July, as on Long Island, some quick-maturing early crop can be produced before the cauliflower is planted. This, however, is not a common practice except where manure is used to keep up the humus supply. Plowing should be done early enough to allow the humus to decay before the cauliflower crop is planted.

Soil Reaction.—Cauliflower is sensitive to high acidity. Wessels (1932) has shown that maximum yields on a sassafras silt-loam soil on Long Island were obtained at reactions between pH 5.5 and pH 6.6. As acidity was reduced from pH 4.5 to about pH 5.5 the yields of most strains increased markedly. As the reaction approached neutrality, there was a tendency for the yields to decrease, due probably to decreased availability of some essential element. Workers at the Rhode Island Station obtained similar results. Wessels reported very striking differences in behavior between varieties of cauliflower in their response to varying degrees of acidity; this suggests the possibility of developing strains that are highly resistant to acid-soil conditions.

When cauliflower is to be grown on soil more acid than pH 5.5 it is desirable to reduce acidity by the application of lime. Soil tests should be made to determine the quantity of lime to apply for satisfactory results. Where there is evidence of magnesium deficiency, it is desirable to use lime that contains magnesium.

Manures and Fertilizers.—On sandy-loam soils, manure is valuable and should be used if available at a reasonable price. If manure is not available, soil-improving crops should be turned under to keep up the humus supply. Commercial fertilizer is used even when manure is applied. Where manure is not used cauliflower is heavily fertilized.

Great variation in fertilizer practice exists. Jones, Ernst, and Tavernetti (1935) reported that manure is used at the rate of 10 to 20 tons per acre in some sections of California, while in other sections, heavy applications of nitrogenous fertilizers are used. They do not mention the use of a complete fertilizer, but state that preliminary trials in one district show a response to phosphorus. In New York, growers in three sections follow very different fertilizer practice. In the Catskill Mountain region, manure is used and, in addition, from 1 to 2 tons of a 4–8–7 or 5–8–7 fertilizer is used to the acre; in Erie County, manure is applied in most cases and in addition from 500 to 2000 pounds of a 5–10–5 or some similar analysis fertilizer; on Long Island about 1 or 1¼ tons of 4–8–7 or 5–8–7 fertilizer, per acre. Manure is little used for cauliflower on Long Island, but rye is grown to turn under.

On fairly good silt-loam and clay-loam soils an application of 60 to 80 pounds of nitrogen, 140 to 160 pounds of phosphoric acid, and 60 to 80 pounds of potash ought to give good results. On sandy and sandy-loam soils, 100 to 125 pounds of each of the three constituents should be sufficient. When manure is used at the rate of 15 to 20 tons to the acre, the quantity of fertilizer, especially nitrogen and potash, might be reduced considerably.

Results reported by Robbins, Nightingale, and Schermerhorn (1931) indicate that a marked deficiency of nitrogen may result in premature heading or "buttoning" of cauliflower.

Seed.—The importance of good seed can scarcely be overemphasized. Poor strains are expensive at any price, for these will not produce good marketable heads under the most favorable conditions. Most of the cauliflower seed used in the United States is imported, mainly from Denmark. Seed of the large-growing variety grown during winter and early spring in the Salinas, California, area, is produced in California and the seedsmen have developed excellent strains.

The retail price of good cauliflower seed is very high, often $2 or more an ounce, but it is better to give this price than to plant inferior strains.

Growing Plants.—Cauliflower plants are grown in very much the same manner as cabbage plants. In the North, seed for the early crop is sown in the greenhouse or hotbed and the plants transplanted as described for cabbage. Cauliflower seed is not sown quite so early as cabbage. In the eastern part of the United States the seed for the late crop is sown about the same time or a little later than late cabbage and the plants are handled in much the same manner. In California, seed is planted at various times in the spring, summer, and fall, depending on the type grown and the region in which the crop is produced. The seed of the broccoli type, grown in the Salinas region, is sown in late summer and early fall for winter and early spring crops.

Planting.—Plants for the early crop in the North are usually set out as soon as the danger of hard frosts is over. The late crop, in regions where severe freezing occurs, is planted in time for the heads to mature before the arrival of very cold weather. On Long Island and in the Buffalo, N. Y., region, the planting is done the latter half of July and the first part of August; in the field in California at various times through the summer, fall, and early winter. Planting is done by hand or with machine, the latter being used where the acreage justifies the expense.

The distance for planting varies somewhat, depending on the variety and the richness of the soil. The rows are usually about 3 feet apart and the plants are set 18 to 30 inches apart in the row. The methods of planting are the same as for cabbage.

Cultivation.—In the cultivation of cauliflower the same precautions should be taken as suggested for cabbage for the root systems of the two crops are similar. The weeds should be kept down at all times.

Diseases.—The most important diseases of cauliflower are blackleg, black rot, clubroot, whiptail, and browning. All except whiptail and browning have been discussed under cabbage, and the discussion need not be repeated.

WHIPTAIL.—This disease is not caused by a parasite, but is known as a physiological disease, probably being caused by malnutrition. Clayton (1924) describes it as follows:

> Whiptail plants have narrowed, more or less ruffled leaves with irregular margins. Plants that show extreme symptoms are much dwarfed and produce no head at all, while those showing less marked symptoms produce ricey, leafy culls. This disease is not due to some microscopic organism, but is a response peculiar to the cauliflower plant, and is generally due to unfavorable soil conditions. Hence, whiptail may be classed as a malnutritional disease. The condition is not irreversible, for plants may show whiptail symptoms when very young and later recover and produce normal leaves and heads. Large plants affected by whiptail, however, do not recover.

Whiptail causes considerable loss to cauliflower growers on Long Island. It seems to be associated with soil acidity as applications of lime reduce or eliminate the disease there. In the soil acidity experiments on the Long Island Vegetable Research Farm, whiptail is most prevalent on the plots having the highest acidity, and is practically absent from the plots that are only slightly acid.

BROWNING (BROWN ROT, RED ROT).—This is a physiological trouble apparently resulting from a deficiency of boron. It has been known in the Catskill Mountain region of New York for several years and has been found in other parts of that state. The trouble first appears as water-soaked areas in the stem and in the center of the branches of the curd, as shown in Fig. 39, but the first external appearance is on the surface of the curd. Later, these areas change to a rusty-brown color; in this stage the trouble is known in the Catskill Mountain region as brown rot or red rot. Browning is associated with hollow stem, but many fields of cauliflower with hollow stem have been found to be free of browning. Curds affected with browning are bitter, both in the raw and in the cooked state.

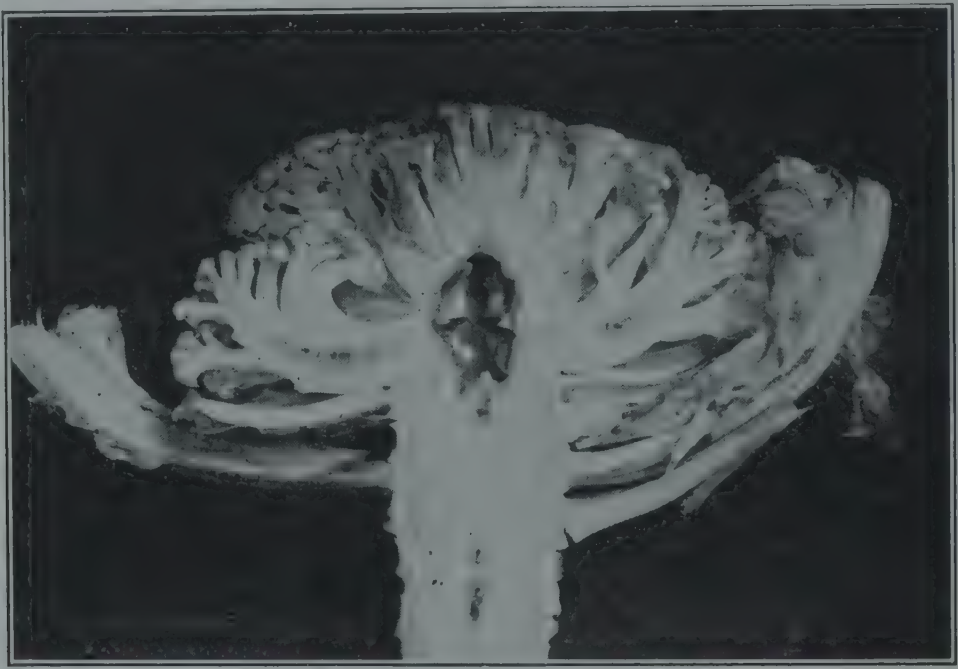

FIG. 39.—Head of cauliflower showing hollow stem and browning, symptoms of boron deficiency. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Results of experiments reported by Dearborn, Thompson, and Raleigh (1936) show that browning is controlled by applications of borax. Table XXXII shows the effects of different rates of application of common borax (sodium tetraborate—$Na_2B_4O_7.10\ H_2O$) on two types of soil in Delaware County, N. Y. Results of experiments conducted in the greenhouse confirmed the results of field experiments. The present recommended practice is to apply 10 pounds of borax to the acre. The borax is mixed with the fertilizer. On alkaline soils a larger application may be desirable, but this can be determined only by experiment.

Insects.—The same insects that are injurious to cabbage are injurious to cauliflower. While the same control measures are used, it is not considered safe to use arsenicals on cauliflower after the heads are formed.

Blanching.—A perfect head of cauliflower is pure white. To obtain this it is necessary to exclude the sunlight. While the head is small it is protected by the small inner leaves which curve over it, but before it is full grown these leaves begin to lift and some other means of covering is necessary. The usual method is to bring the outer leaves up over the head and tie them with straw, raffia, twine, or tape of some kind. By using a different kind of material or a different colored twine each day for several days it is easy when cutting to select those that have been tied the longest. Sometimes two outer leaves are broken over to protect the head but this method is not so satisfactory as tying.

TABLE XXXII.—EFFECT OF BORAX ON GRADE AND ON BROWNING OF CAULIFLOWER ON TWO TYPES OF SOIL

Borax, per acre, lb.	Lackawanna silt loam			Culvers silt loam		
	Grade 1, per cent	Grade 2, per cent	Browning, per cent	Grade 1, per cent	Grade 2, per cent	Browning, per cent
0	43.7	25.5	24.4	21.6	5.2	49.3
5	56.0	30.6	1.3	53.0	18.3	0.0
10	58.1	32.2	0.5	50.2	21.0	0.0
25	55.2	33.4	0.0	60.3	15.2	0.0

The length of time for the blanching of the head depends on the weather. In the hotter part of the season when the plants are growing rapidly, 2 or 3 days will be sufficient, while in cold weather 8 to 12 days may be required. If left too long during hot weather, the leaves begin to rot and discolor the head. In cool weather the heads begin to push up their flower stalks and assumed a "riced" condition if left too long; this reduces their value. They may even begin to branch and this renders them worthless except for pickles. Examination of the heads should be made every day during hot weather and at intervals of every 2 or 3 days in cool weather. It is seldom necessary to examine more than an occasional head of any particular day's tying, as all the heads will be ready about the same time. However, if the heads are developing unevenly it is necessary to examine every head.

Harvesting.—Cauliflower is harvested when the heads attain the proper size and before they begin to rice or become discolored. Medium-sized heads are in greatest demand. In harvesting, the plant is cut off well below the head with a large sharp knife.

The heads are trimmed with a long sharp knife cutting squarely across the leaves, leaving ½ to 1 inch projecting above the head. The stubs left protect the head from injury by rubbing against the crate. The stem of the plant is cut off so as to leave at least one circle of outer leaves and the smaller inner leaves.

Grading.—Cauliflower heads are usually graded into at least two grades and sometimes three. The U. S. Department of Agriculture has promulgated standards for cauliflower and it would seem desirable to use these where careful grading is feasible. Unstandardized grading may be unprofitable as was shown by Hartman (1939) to be the case with cauliflower sold on an auction market on Long Island. In this case, the best cauliflower was packed as No. 1 regardless of quality, provided it was marketable, so that one grower's No. 2 might be as good as another grower's No. 1, and a given grower's No. 2 might be as good at one time as his No. 1 at another time.

Packing.—Cauliflower is packed in various types of boxes, baskets, crates, and barrels. The round-stave bushel basket is used in some regions but is not a popular container for shipping. Crates are now generally used for products to be shipped considerable distances by rail, boat, or truck. Different sizes and shapes of crates are in use. Some are flat for packing one layer of heads, while others are deeper and the heads are packed in two layers. Where two layers are packed, the heads of both layers face outward. Tight packing is important and it is desirable to have all the heads about the same distance from the slats.

Storing.—Cauliflower is not ordinarily stored, but good sound heads can be kept for a short period in cold storage. Results of experiments by Platenius, Jamison, and Thompson (1934) indicate that good cauliflower can be kept for at least 30 days in cold storage at 32°F. In one experiment cauliflower remained in marketable condition for 40 days. When stored at 40°F., deterioration began in about 12 days.

BROCCOLI

There are two types of broccoli, one the cauliflower broccoli (*Brassica oleracea* var. *botrytis*) and the other the so-called sprouting type (*B. oleracea* var. *italica*). The former differs little from cauliflower, but, in general, requires a longer growing season and more space. The cultural requirements for the cauliflower broccoli are essentially the same as for ordinary cauliflower. This crop is grown commercially in California and Oregon. It is not a satisfactory crop in most sections of the country because it requires a fairly long growing season and does not stand hot weather well.

SPROUTING BROCCOLI

During the past few years sprouting broccoli or "green sprouting broccoli" has attracted considerable attention and its production is being attempted in various parts of the United States. This plant forms a head somewhat similar to cauliflower except that it is green in color. In addition to the central inflorescence, it develops axillary flower stalks, particularly after the center is removed. Unlike the cauliflower, sprouting broccoli produces marketable heads for several weeks.

Planting and Care of the Crop.—Early plants may be started about the same time as early cauliflower and transplanted to the field. This method is satisfactory in relatively cool regions only as the heads do not develop well during hot weather. In the vicinity of Norfolk, Va., the plants are set out in July and the crop is harvested during October, November, and December. It requires from 100 to 125 days from seed sowing to heading. The plants will produce side shoots for several weeks so that one planting is sufficient for a continuous supply for the home garden in the North.

The plants are set 18 to 30 inches apart in rows 36 to 48 inches apart. If they are to be allowed to grow throughout the growing season for the harvesting of heads developed on laterals, the spacing should be 24 to 30 inches in the row and the rows 30 to 48 inches apart. Fertilization, cultivation, and general care suggested for cauliflower would be satisfactory for broccoli.

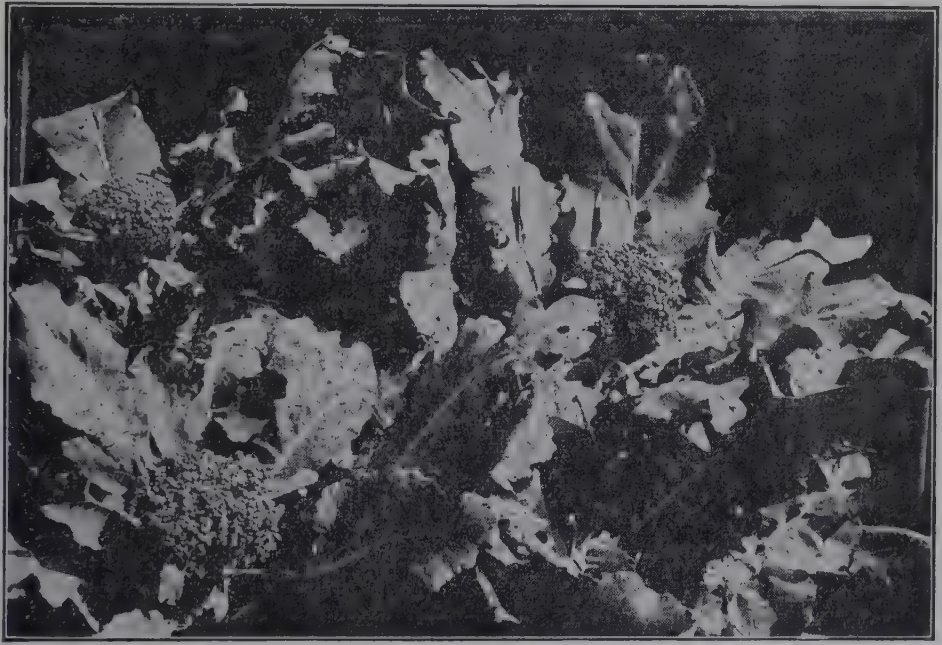

Fig. 40.—Plant of sprouting broccoli showing 3 heads produced from lateral shoots after the central bud had been removed. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

A good strain of Italian green-sprouting broccoli should be grown. Only a few varieties are grown and the Glory of Calabria and Christmas Calabrese are the best known in the United States. The so-called white-sprouting and purple-sprouting varieties are not so desirable as the green.

Harvesting.—The plant resembles cauliflower except that the leaves are more ragged and the central inflorescence develops a longer stem. A cluster of green flower buds, 3 to 6 inches in diameter, develops in the center. At first this head or cluster is compact, but gradually spreads.

The cluster, with 8 to 10 inches of stem, should be harvested before the flower buds open. Lateral shoots develop in the axils of the leaves and these will develop into marketable heads from 1 to 3 or 4 inches in diameter (Fig. 40). These lateral shoots will produce a continuous harvest for several weeks. The smaller shoots are often tied in bunches in preparing them for market, but they are also sold in bulk.

Diseases and Insects.—Many of the pests of cauliflower also attack broccoli.

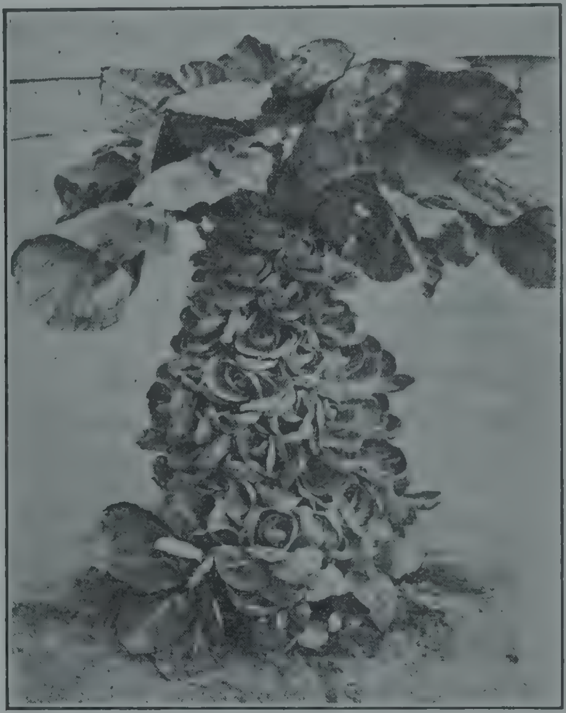

FIG. 41.—Plant of Brussels sprouts showing a large number of partially developed heads on the stem.

BRUSSELS SPROUTS

The edible portions of this plant are the buds or small heads that grow in the axils of the leaves (Fig. 41). The heads, 1 to 2 inches in diameter, are used in the same manner as cabbage and are also pickled.

This crop has been grown in the vicinity of Brussels, Belgium (from which place it gets its name), for hundreds of years. While it is one of the minor crops, it has been increasing in importance and is grown on a fairly large scale in certain sections of California and in parts of New York, especially on Long Island.

Stocks of Brussels sprouts seed are not very satisfactory because they show great variation in type and in performance. Development of high-grade, uniform strains and varieties is greatly needed.

Culture.—The general cultural requirements for Brussels sprouts are about the same as for cauliflower. The plant will stand considerable freezing and may be left out of doors until very severe freezing is expected. On Long Island the plants for the early crop are set out during the latter part of June and early July and for the late crop from July 20 to Aug. 15. The plants are spaced 2 to 3 feet apart in the row with the rows 3 feet apart.

The fertilizer application for Brussels sprouts is about the same as for cauliflower. Manure is used by some growers and in the absence of manure some cover crop is turned under to supply humus. On Long Island, rye is the principal cover crop; for the early crop, the rye is allowed to grow 8 to 10 inches high before being turned under. The late crop sometimes follows early potatoes, but in this case a cover crop is usually plowed under for the potato crop.

Harvesting.—Harvesting begins usually in three to three and a half months after setting the plants. Early sprouts should be picked over several times, the lowest on the plant being taken each time, otherwise these will open out and become yellow. The first picking should not be delayed after the lower leaves begin to turn yellow as the sprouts get tough and lose their delicate flavor. In picking, the leaf below the sprout is broken off and the sprout removed by breaking away from the stalk. As the lower leaves and sprouts are removed, the plant continues to push out new leaves at the top and in the axil of each leaf a bud or sprout is formed. The sprouts are placed in baskets or other containers as picked and carried or hauled to the packing house where they are placed in quart berry boxes. These boxes are packed in the ordinary 32-quart berry crate for shipment.

As freezing weather sets in, the plants are pulled up or cut off near the surface of the ground, hauled to a shed or some convenient place near the packing shed, and stacked. A sheltered place, if available, is selected for stacking. The plants are stood upright on the ground as close together as possible and a light covering of marsh hay, seaweed, or other material is placed over them. Only a light covering is necessary since freezing does not injure the sprouts if they are thawed gradually, but alternate freezing and thawing spoil them. The stacks are only one layer deep.

After the plants are stacked the sprouts may be picked at any time through the winter. The leaves are stripped from the plants before they are brought into the packing house and the sprouts are removed with a small knife. After being removed the sprouts are stripped of the outer, yellow leaves and placed in berry boxes.

For home use Brussels sprouts can be stored in a cool cellar, where they may be kept for a large part of the winter if the conditions are favorable. In mild climates the plants may be left in the field or garden throughout the winter.

KOHLRABI

Kohlrabi is grown for the turniplike enlargement of the stem above ground (Fig. 42). It is little known and not appreciated in the United States, although it is an excellent vegetable if used before it becomes tough and stringy. For good quality the growth should be rapid and without check. The plants may be started in the greenhouse or hotbed for an early crop but the more common practice is to plant the seed where the crop is to mature.

Culture.—The seed is sown in rows 18 inches apart for hand cultivation, or 24 to 30 inches for horse cultivation. The plants are thinned to stand 6 to 8 inches apart in the row. Planting at intervals of 2 to 3 weeks will secure the proper sequence and insure a continuous supply of tender kohlrabi.

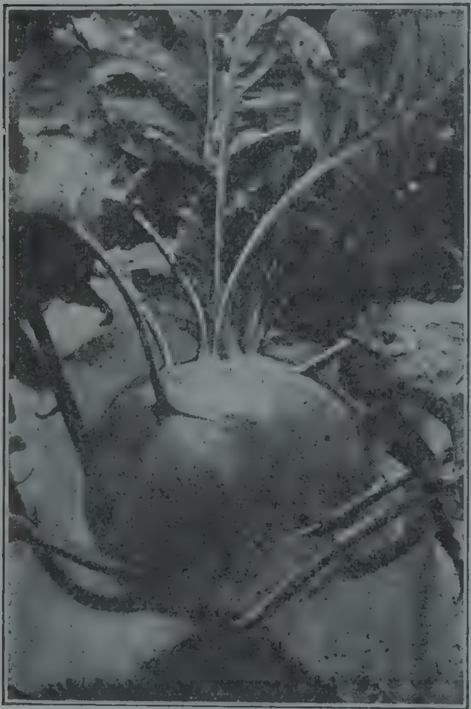

FIG. 42.—Kohlrabi plant showing root, swollen stem and leaves. The edible portion is the turnip-shaped stem.

A rich garden soil will produce excellent kohlrabi. If the soil is not already rich a liberal dressing of manure is desirable. If manure is not available, green-manure crops and commercial fertilizer may be used as substitutes. A fertilizer similar to that suggested for cauliflower would be satisfactory for this crop.

Cultivation similar to that given cabbage or cauliflower is satisfactory for kohlrabi, but when planted in rows less than 24 inches apart hand cultivators are used.

Varieties.—The most popular varieties are White Vienna, Green Vienna, Purple Vienna, and Earliest Erfurt. The White Vienna is probably grown to a greater extent than all of the others combined.

Harvesting.—Kohlrabi should be harvested when the swollen stem is 2 to 3 inches in diameter and before it becomes tough and woody. In preparation for market, the root is cut off and the plants are tied together in bunches like beets, or sold in bulk.

CHINESE CABBAGE

Chinese cabbage is little grown in the United States and is considered a new vegetable although it has been known by authorities in this country for many years. It is grown as a potherb and also as a salad plant. It requires a rich soil, abundance of moisture, and a cool season. Quick, continuous growth is important.

This plant is probably a native of China where it has been in cultivation since the fifth century.

Chinese cabbage is an annual and has few characteristics of common cabbage. Two more or less distinct species are grown, pe-tsai (B. *pekinensis*) and pakchoi (B. *chinensis*). The pe-tsai resembles cos lettuce but produces a much larger head which is elongated and compact; the leaves are slightly wrinkled, green, thin, and much veined. The midrib is broad and light in color. The pakchoi varieties resemble Swiss chard in habit of growth. The leaves are long, dark green, and oblong or oval. This type does not form a solid head.

Culture.—Chinese cabbage thrives best during the cooler portion of the growing season; therefore, in the South it is grown as a winter crop, and in the other portions of the country as a fall crop. Hundreds of attempts have been made to produce Chinese cabbage as an early summer crop, but in most seasons the plants go to seed before forming a head.

When Chinese cabbage is started as a spring crop, the seed is sown in a greenhouse or hotbed and the plants are handled about the same as cabbage. It is important, however, to prevent a check in growth, and, for this reason, the plants should not be allowed to get too large before being set out. It is best to set them in the field within 4 weeks of the time the seed is sown.

As a fall crop the seeds are often sown where the crop is to mature and after the plants become established they are thinned to stand 12 to 15 inches apart, depending on the variety and richness of the soil. Some growers prefer to grow the plants in an outdoor seedbed and to transplant the young plants to the field. If they are to be transplanted the work should be done while the plants are small.

Any rich soil, retentive of moisture and in good physical condition, will produce a satisfactory crop of Chinese cabbage when the other conditions are favorable. Market gardeners select either a good loam or a sandy loam for this crop. A good muck soil is almost ideal for Chinese cabbage since this type of soil is rich in nitrogen and is retentive of moisture. The largest crops seen by the author were produced on mucks.

The general care of the crop is about the same as that given cauliflower, but the length of time required to grow a crop of Chinese cabbage is less than for cauliflower.

Harvesting.—Chinese cabbage is harvested when the heads are fully developed. The heads are cut from the stalk in the same manner as cabbage or cauliflower. The loose, outer leaves are removed as shown in

Fig. 43, and the heads are packed in various ways. All kinds of packages are used since the crop has not become of sufficient importance to demand a special package. Some growers use flat baskets, others use boxes and crates of various kinds. Lettuce boxes are used to some extent and they are fairly satisfactory for the long-headed varieties. The heads are usually laid in the package rather than placed upright, although the latter method has been used in packing in celery crates.

Chinese cabbage has been grown mainly for local markets, but the industry is developing at considerable distances from the consuming centers, therefore a good shipping package is needed.

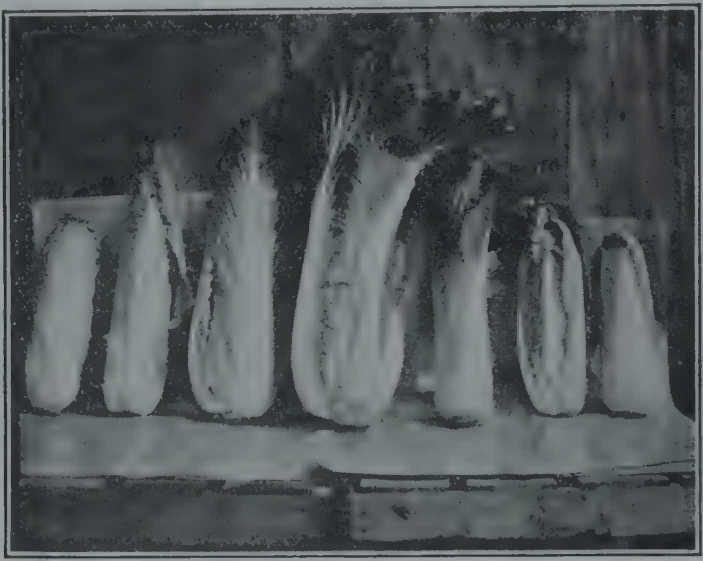

Fig. 43.—Heads of Chinese cabbage, with the outer leaves removed. (*Courtesy of U. S. Dept. Agr.*)

Storage.—In China on the approach of winter, the plants are pulled, the outer leaves are removed, and the heads are stored in an outside cellar. In the United States, storage has not been practiced to any great extent, although successful attempts have been made to store in cold-storage warehouses. At Cleveland, Ohio, Chinese cabbage has been kept thus for 2 months. Mrs. Fred Osborne, Ann Arbor, Mich., stored a carload of Chinese cabbage in cold storage in Detroit during the fall of 1919. The heads were cut from the stalk and placed upright in celery crates. Some of the heads were wrapped in paper while others were not wrapped. Mrs. Osborne reported no difference in keeping between those wrapped and those not wrapped since they all kept in perfect condition for a month.

CHAPTER XX

ROOT CROPS

BEET	RUTABAGA
CARROT	RADISH
PARSNIP	HORSE-RADISH
SALSIFY	TURNIP-ROOTED CHERVIL
SCORZONERA OR BLACK SALSIFY	SKIRRET
SCOLYMUS OR SPANISH SALSIFY	CELERIAC
TURNIP	

These root crops thrive best in a cool season and in a deep friable soil. When produced in the South they are grown during the winter. Those requiring only a short growing period do better in spring and fall than in midsummer. Since all the root crops are hardy, they may be planted early in the spring in the North and may be left in the field or garden until late in the fall.

All the root crops listed above have similar cultural requirements. When grown for market they are produced on an intensive scale. Seeds are nearly always sown where the crop is to mature, the only exception being the beet, seeds of which are sometimes sown in a greenhouse or hotbed for a very early crop.

While the root crops are not of so much commercial importance as many of our vegetables, some of them are grown in nearly all home gardens and in most market gardens. They are grown to some extent as truck crops to be shipped to distant markets, but not to so great extent as most of the other well-known vegetables.

BEET

The garden beet is an important home-garden crop and is grown on a small scale by a large percentage of market gardeners. It is grown also for shipment to distant markets and for canning. The commercial crop of 1937 was estimated by the U. S. Department of Agriculture at 19,150 acres with a cash income of $1,454,000. These figures include beets grown for market and for canning in the important states, but do not represent the total crop grown in the United States.

History and Taxonomy.—The garden beet is probably a native of Europe, and while it has been known since about the third century it is essentially a modern vegetable. The first appearance of the improved beet in Germany is recorded about 1558 and in England about 1576. It was mentioned by McMahon in 1806 as being grown in the gardens of America at that time, although it is not definitely known when it was first brought over.

The beet is a member of the Chenopodiaceae or goosefoot family. The garden beet, stock beet or mangel, sugar beet, and chard belong to the same species, *Beta vulgaris*. It usually behaves as a biennial, producing a thickened root and a rosette of leaves the first year, and flowers and seed the second year. Under some conditions, mentioned later, the plant produces flowers and seed the first year. The flower stalk grows to a height of about 4 feet. The calyx continues to grow after flowering, becomes corky, and completely covers the seeds. This forms what is commonly called the beet seed; in reality it is a fruit containing usually two to six seeds. The true seeds are small, kidney shaped, and brown in color. They retain their germinating power for 5 or 6 years.

Soil Preferences.—While beets are grown on nearly all types of soil, they thrive best on a fairly deep, friable loam, moist but well drained. Where large yields are most important, as for canning or for the fall and winter market, a deep rich alluvial soil such as a silt loam is considered very desirable. Muck soil is almost ideal for late beets since it is loose and moist. Heavy soils are not satisfactory since beets are likely to be unsymmetrical in form when grown on such soils. It requires less labor to care for a crop of beets on a loose friable soil than on a heavy compact soil.

The soil for beets, and all of the other root crops, should be thoroughly prepared and the surface should be loose and smooth. It is difficult to plant and care for a crop of beets on poorly prepared land. Good preparation is more essential for crops cultivated by hand than for those cultivated by horse-drawn cultivators, since hand cultivators are light and not adapted to heavy work or for work in rough cloddy soil. After the soil has been thoroughly pulverized, it is desirable to smooth the surface with a meeker harrow or drag just before planting the seed.

Manures and Fertilizers.—Beets must make rapid and continuous growth to develop the highest quality; therefore, a good supply of available nitrogen, phosphorus, and potash is necessary. On sandy and sandy-loam soils, manure is valuable to supply humus as well as fertilizing elements; on heavy soils it is of importance in improving the physical condition by making them more friable. It is best, however, to apply fresh manure to a crop preceding beets on account of the weed factor. Well-rotted manure may be applied to the land without danger of introducing weed seeds. When manure is used at the rate of 10 to 15 tons per acre on silt, silt-loam, and clay-loam soils, the fertilizer used should be relatively high in phosphorus; a 1–3–1 ratio is suggested. An application of fertilizer supplying 30 to 40 pounds each of nitrogen and potash and 90 to 120 pounds of phosphoric acid should give good results. For sandy and sandy-loam soils with 10 to 15 tons of manure, the fertilizer should supply more nitrogen and potash than suggested for heavier soils. An application of 60 to 80 pounds each of nitrogen and potash and 120 to 140 pounds of phosphoric acid should give good results.

When manure is not used, it is desirable to use soil-improving crops to maintain the humus supply and to apply liberal quantities of fertilizer. For sandy and sandy-loam soils a 1–2–2 ratio is suggested and the application should supply 75 to 100 pounds of nitrogen and 150 to 200 pounds each of phosphoric acid and potash. On heavier soils, 60 to 80 pounds each of nitrogen and potash and 140 to 160 pounds of phosphoric acid should give good results. When beets are grown on good muck soils that have been cleared recently, an application of 30 to 45 pounds of nitrogen, 120 to 180 pounds of phosphoric acid, and 180 to 250 pounds of potash is recommended. On mucks that have been well fertilized for 10 years or more, an application of 40 to 60 pounds of nitrogen, 80 to 120 pounds of phosphoric acid, and 120 to 180 pounds of potash is recommended.

Results of many experiments indicate that the beet plant is sensitive to soil acidity. Hester, Parker, and Zimmerley (1936) showed marked increases in yield at Norfolk, Va., as the acidity was reduced from pH 5.0 to pH 5.8. The yields at pH 5.8, pH 6.5, and pH 7.0 were essentially the same. Results of experiments in other states are in agreement with those obtained in Virginia.

Planting.—A large part of the beet crop is grown from seeds planted where the plants are to mature, but a few early beets are grown from plants started in a greenhouse or hotbed. In growing plants for transplanting, the seed is sown several weeks prior to the time for outdoor planting. The plants may be allowed to grow in the seedbed until time to set them in the field or garden, or they may be transplanted to flats, spacing them about 1½ inches each way as described for celery. By growing plants as described, it is possible to get beets large enough for market 2 to 3 weeks earlier than is possible by planting seed in the garden. The transplanting method is expensive and is justified only where high prices can be obtained.

Beet plants are fairly hardy so, in regions where hard freezes do not occur, seed may be planted during late summer, fall, and winter. Where hard freezes do occur, planting should be delayed until the danger is over. For a succession of young tender beets, several plantings should be made, the number depending on the length of the growing season. The main crop, grown for canning or for fall and winter market in the North, is planted during May or early in June.

When beets are grown intensively and cultivated by hand, the rows are spaced from 14 to 18 inches apart, but for horse or tractor cultivation the rows are spaced 24 to 30 inches apart. When seed is sown with drills and at the closer spacing mentioned, from 4 to 6 pounds is required. Since the seed (beet ball) is uneven in size and irregular in shape, it is difficult to get even distribution, but by screening to separate the seed into various sizes, fair distribution can be made.

Beet plants sometimes shoot to seed before the roots reach marketable size. Results of experiments reported by Chroboczek (1934) show that if the plants are subjected to relatively low temperature (40° to 50°F.) for 15 days or longer, some seeding is likely to occur in the field. When the treatment was 30 days at 40° to 50°F., 47.69 per cent of Crosby Egyptian plants went to seed in the field before the beets reached marketable size. When plants were grown in a cool greenhouse for two months or more and then grown subsequently in the field, most of them went to seed, as shown in Fig. 44.

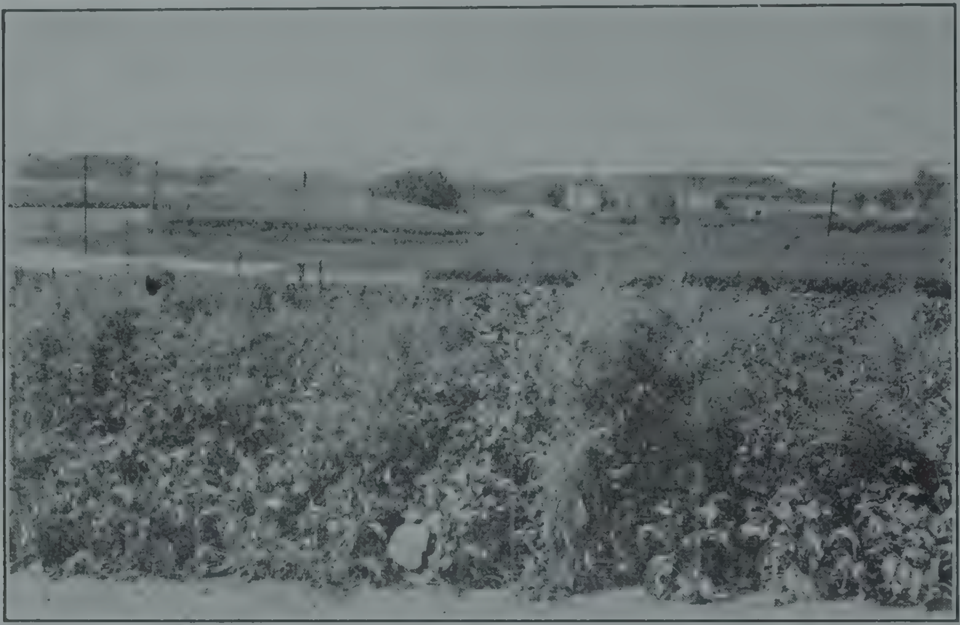

Fig. 44.—Premature seeding of beet plants. The plants in the row marked with a hat were grown in a greenhouse at 60 to 70° F. prior to planting in the field and produced no seed stalks. The plants in the next row to the right were grown at 50° to 60° F. prior to planting in the field and 94 per cent of them produced seedstalks. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Thinning.—Thinning is necessary no matter how evenly the seed has been planted, since each fruit contains more than one seed. The plants come up in clumps and all but one of these should be removed. Very often thinning is delayed until the beets are large enough to use, when the larger ones are removed and the small ones left to develop. Those left to mature should be spaced 3 or 4 inches apart.

Cultivation.—Clean, shallow cultivation should be given as needed to control weeds. Experimental results given in Chap. X indicate that yields of beets were not increased materially by maintaining a soil mulch. Cultivating after the crop was about half grown was of little or no value. When there are no weeds, late cultivation is likely to do more harm than good, because the destruction of roots more than offsets any benefits that might be derived from the soil mulch. Many of the roots of the beet plant are found near the surface, as shown in Fig. 45. Cultivation to the depth of 2 inches would have destroyed all the roots shown in the illustration. Most cultivation of beets is done by hand cultivators or small tractor cultivators. The knife attachments of these machines are efficient in killing weeds and destroy few roots so that these are advised for most cultivating. Hand weeding sometimes is necessary to keep down weeds in the row.

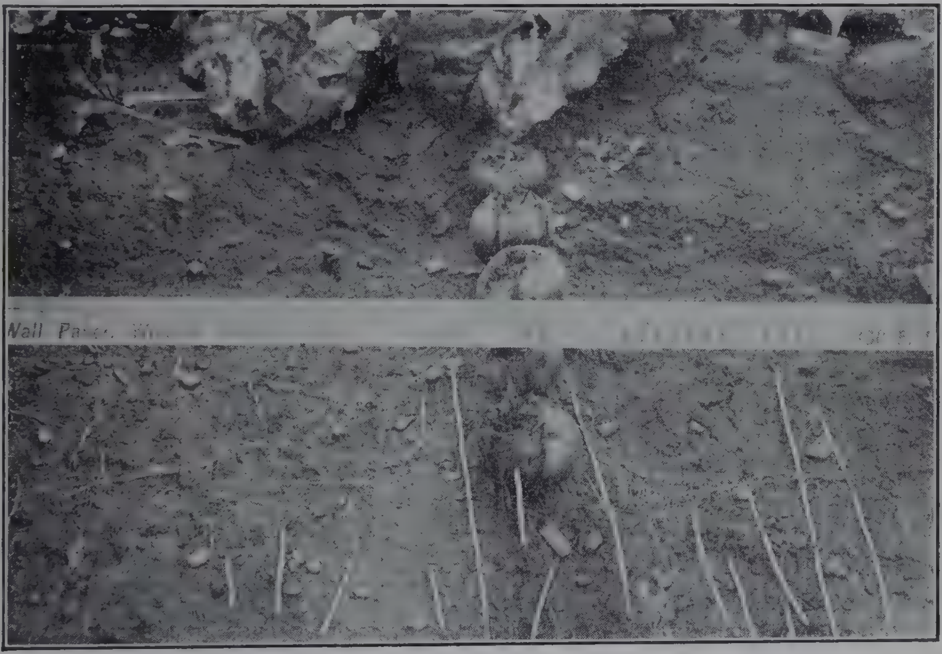

FIG. 45.—Roots of the garden beet uncovered by washing off the soil to the depth of 2 to 3 inches. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Varieties.—The most popular varieties of early beets are Crosby's Egyptian and others of the Egyptian type, followed by Eclipse. Other early varieties grown to some extent are Early Model, Edmand's Early, Early Blood, and Crimson Globe. The Detroit Dark Red is the most popular late variety, followed by Edmand's Blood Turnip. For canning, the Detroit Dark Red is the most important.

Crosby's Egyptian will reach bunching size in about 60 days from seed sowing under favorable conditions Detroit Dark Red requires about 65 days and Crimson Globe 65 to 70 days to reach good bunching size. Half Long Blood is grown to some extent for storing for winter and spring use, but the roots are too long to be popular on most markets, and the crop is more difficult to harvest than the more globular varieties. Ritchie (1927) has published brief descriptions of several of the varieties mentioned.

Diseases and Insects.—The beet crop is not seriously injured by many diseases and insects. The scab, leaf spot, and internal black spot are diseases sometimes injurious and the beet leaf miner and webworm are insects that cause considerable loss under some conditions.

SCAB.—This is caused by the same organism as the potato scab. It does not thrive on a soil that is very acid, but it is not safe to make the soil sour enough to control the scab because this would interfere with the growth of the beet crop.

LEAF SPOT.—Leaf spot (*Cercospora beticola*) is very widespread in the eastern and middle states. The spots are ashen gray, surrounded by a purple border. The spot often drops out and the leaf presents a shot-holed appearance. A large part of the green tissue of the leaves may be destroyed or the leaves may die, in which case they blacken and remain standing. As the leaves die new ones are formed thus elongating the crown.

Cleaning up the refuse after harvesting the crop and practicing rotation are beneficial. Thorough spraying with Bordeaux mixture affords some control but it is seldom practiced.

INTERNAL BLACK SPOT.—This is a physiological breakdown and probably is the same as the trouble known as beet girdle in some regions. Walker (1938) gives the following description of it:

> The outstanding signs are within the root. They consist of black spots irregular in size, shape, and location but uniform in the fact that they are black in color, and hard or corky in texture. . . . The characteristic zones of the beet consist of a series of alternating layers of thin-walled and thick-walled cells. The latter are more conspicuous as the "rings" which one sees most readily. It is between the rings in the thin-walled layer that the black spot starts and for the most part remains. The disease may appear in the outer rings only, inner rings only, or promiscuously throughout. . . .
>
> The disease also affects the leaves. . . . There is a fairly close correlation between the top symptoms and internal black spot. A small percentage of plants may, however, show evidence of the disease in the foliage without root blackening and vice versa. The youngest leaves are the ones always first to show the disease. They are distorted in shape, often one-sided, and commonly longer and narrower than normal, while there is a tendency for the red color to become intensified. In later stages the affected leaves die early and drop off while new leaves, stimulated to form earlier than usual, also eventually take on these signs and finally succumb.

A disease of sugar beets and mangels has been reported from various parts of Europe under the name of heart rot or crown rot. This trouble seems to result from boron deficiency.

According to Walker, internal black spot was corrected in Wisconsin by application of borax. He states that the borax may be applied broadcast or in bands beside the row and along with the fertilizer. Walker suggests 40 pounds of borax to the acre for Wisconsin conditions. Rates of application have not been worked out in other regions and for different soil types and, since borax is toxic when applied in considerable quantities, it is suggested that various rates from 20 to 60 pounds be tried on a small scale at first.

Beet Leaf Miner.—The larva is a white maggot, about ⅓ inch long, which burrows in the tissue of the leaves of beets, chard, spinach, and lamb's-quarters. It feeds on the tissues between the upper and lower layers of the leaf and often causes serious injury by rendering the foliage unfit for food and checking the growth of the plant. Infested leaves present a blistered appearance.

Since the larva lives within the tissue of the leaf, it cannot be reached by poisons. Destruction of fallen leaves and other refuse by plowing immediately after harvesting the crop will aid in controlling this pest since it passes the winter under rubbish in the field. Destruction of lamb's-quarters is also advised. Planting crops early in the spring, or late in autumn, when the insect is not present, is practiced in growing spinach where this insect is serious.

Webworms.—At least two species of webworms attack beets by eating the leaves. The eggs are deposited on the leaves and the larvae attack the foliage, either spinning small webs among the tender leaves or else feeding on the underside, protected by a small web or with no protection whatever.

Spraying or dusting with arsenicals will aid in controlling this insect if care is taken to cover the underside of the leaves.

Harvesting.—Beets for bunching are often harvested as soon as they attain a diameter of 1¼ to 1½ inches. Very often this is a thinning process, the larger ones being removed each time, thus allowing the small ones room to develop. After they reach 2 inches in diameter, bunch beets are not in great demand. The beets are pulled by hand and the injured or dead leaves are removed before being bunched. Four to six beets are tied together, with the tops on, and then they are washed to remove any adhering soil. When bunched beets are shipped considerable distances the tops are often cut back about half way and the bunches are packed in boxes, crates, or baskets.

The late crop of beets is pulled by hand or loosened with a plow. The tops are removed as soon as they are harvested and the beets are packed for shipment or put in storage. They are packed in boxes, crates, baskets, or bags and no particular grading is done, although the very large roots, the small ones, and those injured in any way are discarded.

Storing.—Beets are very often stored in outdoor pits or banks and in common storage houses of the types described in Chap. XV. The best temperature for beets is near the freezing point, but they should not be allowed to freeze. The air in the storage house or cellar should be kept rather humid to prevent wilting and withering of the roots. Beets keep well in cold storage at a temperature of about 32°F., and this type of storage is being used.

CARROT

The carrot (*Daucus carota*) is a very popular vegetable and is increasing in importance, due to the fact that its value in the diet is better understood than it was formerly. It is especially desirable for children and its use is advocated by doctors and dieticians. The carrot is valuable for vitamins A, B, and C, being particularly rich in vitamin A.

Statistics of Production.—Carrot production has increased markedly during the period from 1923 to 1937. According to estimates of the U. S. Department of Agriculture, the acreage in the important states increased from 7,860 acres in 1923 to 38,540 acres in 1937. The estimated average annual acreage, production, and value of the commercial crop by 5-year periods are given in Table XXXIII.

TABLE XXXIII.—AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF CARROTS BY 5-YEAR PERIODS, 1923 TO 1937

Years	Acreage	Yield per acre, bu.	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1923–1927	13,762	316	4,347	$0.67	$2,917
1928–1932	27,580	367	10,127	0.55	5,568
1933–1937	36,012	356	12,836	0.54	6,939

In 1937, California produced over half of the commercial acreage of carrots, 20,470 acres; Texas was second with 7,800 acres; and New York, New Jersey, and Arizona followed with 1,700, 1,400, and 1,200 acres respectively. Most of the increase in production has been in those sold fresh as bunched carrots.

History and Taxonomy.—The carrot is a native of Europe, Asia, and northern Africa, and possibly North and South America. It was probably cultivated by the ancients, but was not a common food plant. It is now grown throughout the world, but is more appreciated in Europe than in America.

It is a biennial of the Umbelliferae or parsley family. The genus Daucus, to which the carrot belongs, contains about 60 species, some of which are native in North America. Very few of them are cultivated. During the first year a thickened root and a whorl of leaves are formed; at the beginning of the second year the flower stalk starts from the crown and grows to the height of 2 to 3 feet.

Soil Preference.—The carrot, like the beet, thrives best in a deep, loose, loamy soil. It is grown commercially on sandy loams, silt, silt loams, and muck soils. For an early crop a sandy loam is preferred but for large yields silt, silt loam, or muck is preferred, the last mentioned being especially desirable because of its fine, loose texture. Carrots do not grow well on a soil that is highly acid. Experiments in Virginia and in New York indicate maximum yields around pH 6.5. Yields were extremely low at pH 5.2 or below, in fact there was practically no yield at pH 5.0 at Riverhead, N. Y.

Manures and Fertilizers.—The discussion of manures and fertilizers for beets applies equally well to carrots. The carrot is considered by many gardeners to be especially "hard on the land" probably due to its heavy draft on the supply of potash. Muck-soil truckers report smaller yields of celery and onions following carrots than following any other crop. A yield of 10 tons of carrots will remove about 100 pounds of potash, 32 pounds of nitrogen, and 18 pounds of phosphoric acid.

Planting.—The carrot is grown from seed planted where the crop is to mature. It is hardy and the seed may be planted in the North as soon as hard freezes are over in the spring and in the fall or winter in the sections of the South where hard freezes do not occur. For a succession of tender roots, two or three plantings should be made. The last sowing of a quick-maturing variety may be made as late as 2 months before the average date of the first killing frost in autumn. The varieties requiring a long growing season, commonly called late, require from 4 to 5 months to mature. Since many consumers prefer small roots the practice of growing early, small-rooted varieties throughout the season is becoming popular, although the half-long varieties are more largely planted for sale for fall and winter use.

Two to three pounds of carrot seed is sown per acre when the crop is to be cultivated by hand, which is the common practice. The rows are spaced 12 to 18 inches apart and the seed is sown with a drill where a considerable quantity is planted. In the home garden, the seed is sown by hand in a shallow trench made with the handle of a hoe or rake as described in Chap. IX. Carrot seed is covered ½ to ¾ inch in depth, the greater depth being on light, dry soil.

Since carrot seeds germinate slowly, radish seeds are sometimes sown with them in the home garden to mark the rows so that cultivation may begin soon after planting.

Environmental Factors on Growth and Color.—In sections of the South where carrots are grown during the winter, the roots sometimes fail to develop a good color. Various explanations have been offered to account for this, including short days, low light intensity, high soil moisture, and relatively low temperature. Results of studies by Barnes (1936) indicate that low temperature is the main factor. Carrots grown in the greenhouse at 50° to 60°F. developed poor color, those grown at 60° to 70°F. were good in color, while those grown at 70° to 80°F. did not have so good color as those grown at 60° to 70°F. Temperature had a marked effect also on the shape of the carrot root, the highest temperature producing the shortest root and the lowest temperature (50° to 60°F). producing the longest root, as shown in Fig. 46. Shape and color of root were affected somewhat by soil moisture, but not so much as by temperature. At low moisture, roots were longer than at medium or high moisture.

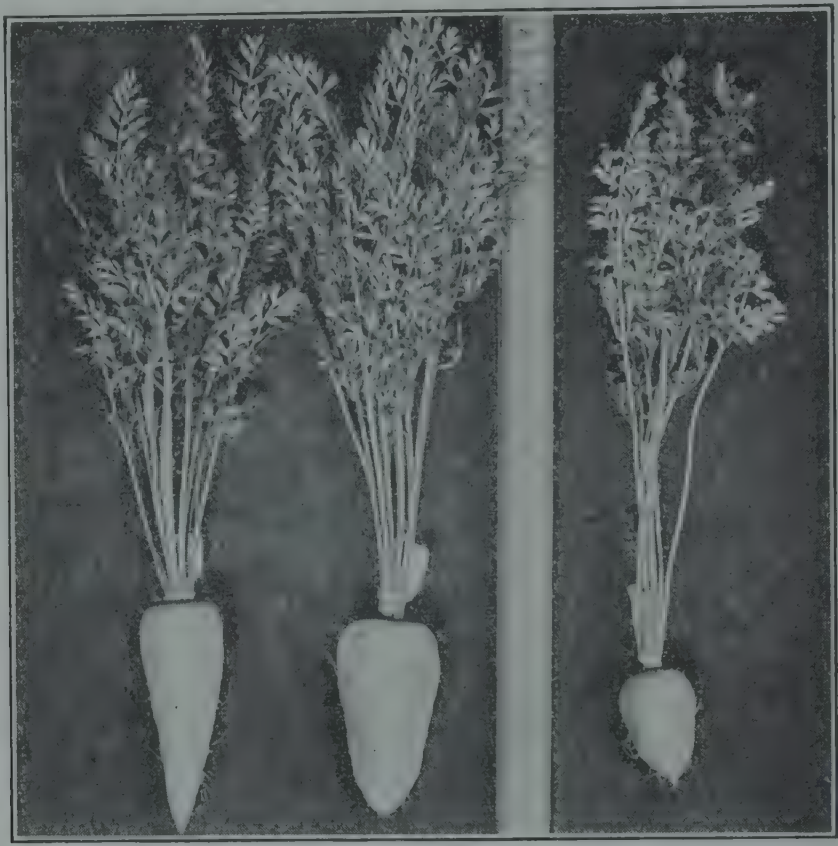

FIG. 46.—Effect of temperature on the shape of carrot roots. Plant on left was grown at 50° to 60° F., the one in center was grown at 60° to 70° F. and the one on the right was grown at 70° to 80° F. (*Courtesy Cornell Univ. Agr. Exp. Sta.*)

Thinning.—Carrots usually require thinning, an expensive and laborious task. As soon as the plants become well established they are thinned to stand 2 to 4 inches apart in the row. For small-growing varieties which are to be marketed as bunched carrots, a space of 2 inches, or even less, between plants is sufficient and for the larger varieties grown for human consumption a space of 4 inches is ample. On muck soil less space is usually given since the soil is so loose that there is no danger of the roots becoming deformed due to crowding. In fact it is desirable to have the plants stand rather thickly on a loose, rich soil to prevent them from growing too large. Small to medium-sized roots are preferred to large ones. In the home garden, and to some extent in the market garden, the first thinning consists of removing surplus plants where they grow in clumps, leaving only one plant in a place. Later thinning is done when the larger roots are of sufficient size to be used. The larger ones are removed and the smaller ones left to develop.

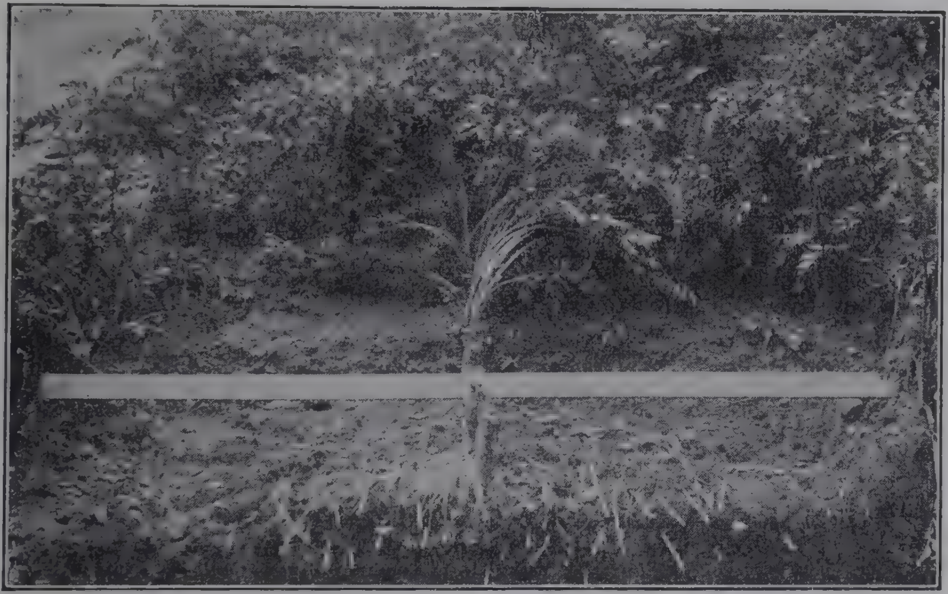

FIG. 47.—Roots of carrot uncovered by washing off the surface soil to the depth of 2 inches (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Cultivation.—Cultivation to keep down weeds is very important especially in the early stages of growth. Since the carrot grows very slowly for the first few weeks, it cannot compete successfully with weeds. Shallow cultivation with hand cultivators is usually given and the knife attachments are used when there is considerable weed growth. Cultivation for the purpose of maintaining a soil mulch does not seem to be of much value. Experiments carried on at Ithaca, N. Y., for 6 years showed insignificant difference in yields between plots on which a soil mulch was maintained and those without a mulch. Similar results were obtained in an experiment carried on for 6 years on a silt loam on Long Island. Deep cultivation is likely to be injurious as many roots are found within 2 inches of the surface, as shown in Figs. 47 and 48.

Varieties.—Seedsmen list a large number of varieties of carrots but only a few of them are of any great importance. The most popular varieties are Red Core Chantenay, Danvers Half Long, Nantes, Morse Bunching, Imperator, and Perfection. The long, bunching varieties have been increasing in importance in recent years in all producing regions.

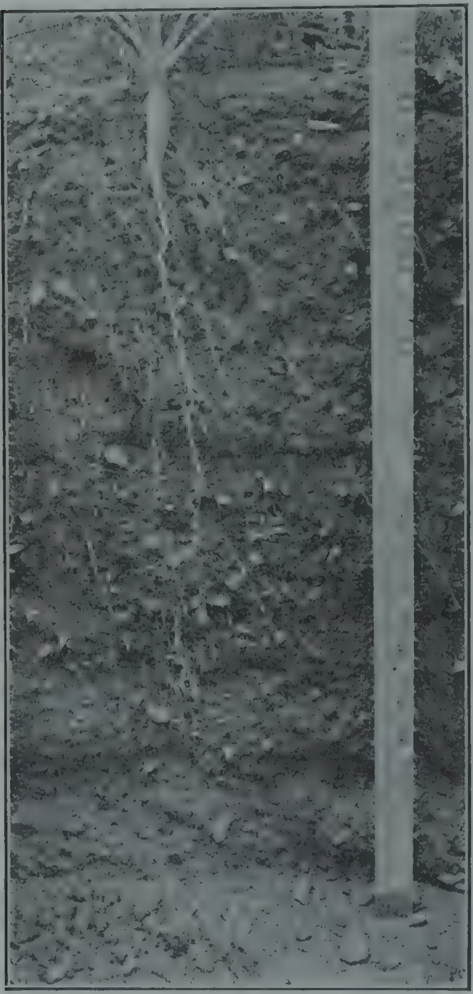

FIG. 48.—Roots of carrot growing down into the soil to the depth of 2 feet or more. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Carrot Rust Fly.—The larvae of the carrot rust fly (*Psila rosae*, Fab.) cause serious injury to carrots in many sections of the United States and Canada. They also feed on the roots of celery and parsnips. The larva burrows into the roots of these vegetables, and when present in large numbers, often renders them unfit for market. The injury to celery is caused by the larva eating the small roots, thus causing a weakening of the plant. The adult fly is about ⅙ inch long, dark green, almost black in color. The maggot or larva is yellowish white in color, slender, and a little over ¼ inch long. The insect passes the winter in the pupa stage in the soil, and sometimes as larva in carrots in storage. The adult fly issues late in spring or early summer (in May in New York) and deposits eggs in cracks in the soil close to the plants and sometimes on the plants themselves. According to Herrick (1925) the eggs hatch in from 12 to 19 days, and the larvae usually mature in about 4 weeks, but may take 6 or 7 weeks. There are two broods in New York and the second one is the most destructive due to greatly increased numbers, since many of the insects perish during winter.

No satisfactory practical control measures have been worked out. Late planting (about June 1 in New York) is recommended where this is feasible, since if no crop is available for the larvae of the first brood there will be no second brood. Late planting of carrots is of little or no avail if a crop of early celery is grown, since the larvae of the first brood would live on the roots of the celery plants.

Harvesting.—Carrots for bunching are often harvested as soon as the roots are ½ to ¾ inch in diameter at the upper end. This may be a thinning process. When the entire crop is to be removed at one time and the roots are long, a plow may be used to advantage by running it close to the row throwing the furrow away from the plants. The roots can then be pushed sideways and pulled with ease.

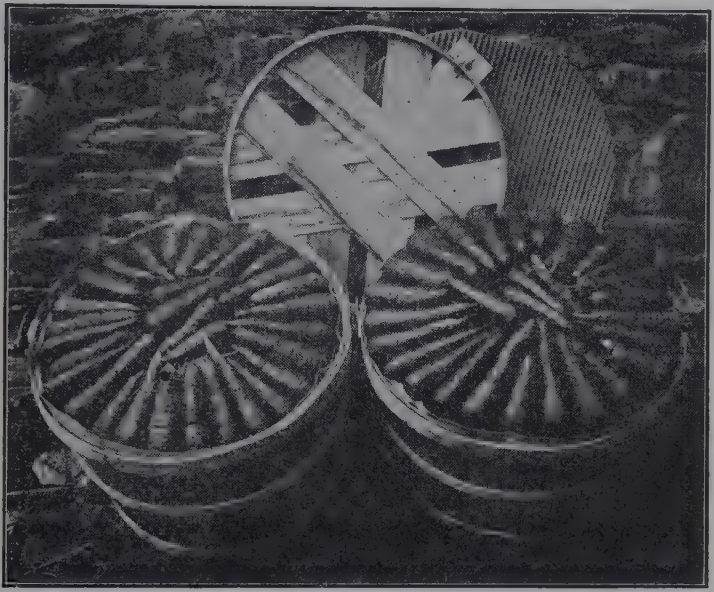

FIG. 49.—Carrots packed in bushel baskets and ring faced. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Early carrots are nearly always bunched in preparation for market. The tops are left on and the roots are tied in bunches. The size of bunch varies considerably, but one containing 5 or 6 carrots is perhaps the most common. On some markets, however, the bunches contain from 8 to 12 carrots each. Bunched carrots are practically always washed before being put on the market. When sold locally the bunches often are loaded into trucks without containers, but when shipped they are packed in crates, boxes, baskets, and hampers. The bushel basket is a popular container.

Late carrots, grown in the North, are usually topped as harvested and are sold by weight or by measure. In the past it has been the practice to ship unbunched carrots without washing, but some growers are now washing the roots before they are packed. The washed product is much more attractive than the unwashed.

Carrots are seldom sorted into definite grades, but it is usually profitable to discard the very large, the small, the crooked and branched roots, as well as those that are injured or diseased. It is particularly desirable to sort out all roots that are badly injured by the carrot rust-fly maggot.

Topped carrots are packed in boxes, crates, baskets, and bags. The bushel basket is being used to a considerable extent and when this container is well packed with a good product, ring faced as shown in Fig. 49, it makes an attractive display.

Storage.—Carrots are stored in the same manner as described for beets. They will keep in good condition for 6 months at high humidity (93 to 98 per cent) and at a temperature of about 32°F. Hasselbring (1927) reported that carrots deteriorate in quality in storage owing to slow loss of sugar in respiration. Platenius (1934) showed that the loss of sugar is slow and that carrots retain a high degree of quality and food value for at least 5 months under good storage conditions.

PARSNIP

The parsnip (*Pastinaca sativa*) is not a very important commercial crop, due largely to the fact that it requires a long growing season, so that no other crop can be grown on the land during the same season. On high-priced market-gardening land, growers produce two, three, or more crops a season. In addition to this the parsnip is not a popular vegetable. According to the Census Report the value of the commercial crop in 1919 was $244,435 and the value of the product per acre was $289.

History and Taxonomy.—The parsnip is a native of Europe and Asia. It is found growing wild in America, but only as an introduced weed. It has been used as food from an early period, and was undoubtedly known to the ancient Greeks and Romans. It was brought to America by the early colonists and was in cultivation in Virginia as early as 1609 and in Massachusetts in 1629.

The plant is a biennial of the Umbelliferae or parsley family, but the crop is grown as an annual. The second year the seedstalk develops from the enlarged root produced during the preceding season.

Soil Preferences.—A deep, rich soil is essential for successful growing of this crop. On a shallow soil the roots become crooked and often branched. Heavy soils are objectionable because of the difficulty of securing a good stand of plants and smooth roots. Since the seeds are very slow to germinate the surface of a heavy soil becomes baked before the plants have a chance to break through, hence a poor stand usually results.

The methods of preparing the soil for the parsnip are the same as for the beet.

Manures and Fertilizers.—The manure and fertilizer treatments suggested for beets should give satisfactory results for parsnips under similar conditions.

Planting.—Parsnip seed is planted where the crop is to mature. Since the seed is slow to germinate and the crop requires a long season, planting is usually done fairly early in the spring when the soil is moist. The seed retains its vitality only 1 or 2 years and should be planted thickly. It is usually sown in drills about 15 to 18 inches apart for hand cultivation and 24 to 30 inches for horse cultivation. One ounce of seed will plant about 200 feet of row and 3 to 4 pounds is usually planted to the acre when the rows are about 15 inches apart. The seed is covered ½ to ¾ inch deep. In the home garden it is desirable to sow some radish seed with the parsnips so that cultivation can begin before the parsnip plants break through the surface of the soil.

After the plants are well established, in 5 or 6 weeks, they are usually thinned to stand 2 to 4 inches apart in the row.

Cultivation.—Cultivation should begin as soon as weed growth starts, or as soon as a crust begins to form. It can begin in a few days after planting if radish seed has been sown with the parsnip seed. It is important to keep down weed growth by cultivating and weeding until the plants are large enough to smother the weeds in the row. During the early stages of growth, parsnip plants are delicate and cannot compete successfully with weeds.

Hand cultivation is commonly given and the knife attachments are used to a considerable extent, especially when the parsnip plants are small.

Varieties.—Very few varieties of parsnips are listed by American seedsmen. Two of these, Hollow Crown and Guernsey, are used by a large percentage of growers. Long Dutch, Model, and Offenham Market are grown to some extent.

Harvesting.—Parsnips are usually left in the ground until late in the fall or even throughout the winter. In many sections they are left in the garden until wanted for use, but where severe freezing occurs this is not satisfactory because it is difficult to dig them when the ground is frozen. The common practice in the North is, therefore, to harvest the roots late in the fall and store them where they are available when wanted. Since parsnip roots grow to considerable length, 10 to 12 inches, they are difficult and expensive to dig. They may be dug by hand with a spading fork or they may be loosened with a plow. When a plow is used it is best to run it close to the row and throw the furrow away from the plants and then loosen the roots by pushing them toward the furrow. Care should be taken to prevent breaking the roots.

After digging, the tops are removed and if the parsnips are to be marketed immediately they should be washed. The roots are packed in various types of packages, including baskets, hampers, crates, and boxes.

Occasionally young, tender parsnips are harvested and sold in bunches with the tops on as described for carrots and beets. Four to six specimens are put in a bunch. This practice is more common in Europe than in America.

Storage.—The same methods of storage are used for parsnips as for beets and carrots. A large part of the crop is sold during the winter and early spring, hence storage is important in regions where the soil remains frozen during most of the winter.

It is believed by many that freezing is necessary for the development of good quality in parsnips, but Boswell (1923) has shown that this is not true. Parsnips stored for 2 weeks at 34°F. attained a quality equivalent to those left in the field for 2 months in late fall at College Park, Md. At 34°F. the change from starch to sugar, mainly sucrose, was rapid and resulted in a marked increase in quality.

SALSIFY

Salsify (*Tragapogon porrifolius*), also known as "vegetable oyster" because of its flavor, is of minor importance in this country but is deserving of greater use. It is a native of southern Europe and is of recent culture, probably not being grown as a food plant until about 1600. It is a hardy biennial belonging to the Compositae or sunflower family. The leaves are very narrow resembling those of the leek but smaller.

Culture.—Salsify requires a long growing season for full development; its culture is practically the same as that given parsnips. The seeds are sown in drills 12 to 15 inches apart and the plants thinned to stand about 2 inches apart in the row.

As salsify is hardy it can be harvested throughout the winter in most regions, but in order to obtain a continuous supply for use or for market it is desirable to store a part of the crop. It may be stored as described for beets.

The roots are prepared for market by cutting away all but 2 or 3 inches of the leaves, washing the roots, and tying ten or more plants in a bunch. The bunch is usually tied tightly near both ends.

SCORZONERA OR BLACK SALSIFY

Scorzonera (*S. hispanica* Linn.), also known as Black Salsify, is a perennial, native of central and southern Europe. It belongs to the Compositae family and is grown in the same manner as salsify, except that it is given more room. The roots are long and black and are boiled after being soaked in water to remove the bitter taste.

This plant was known in Spain about the middle of the sixteenth century for its medicinal properties. It is grown in Europe as a food plant but is practically unknown in America.

SCOLYMUS

Scolymus, or Spanish Oyster plant (*Scolymus hispanica* Linn.), is also a native of Europe and a member of the Compositae family. It is grown and used in the same way as salsify. The root is longer and produces a larger yield. When cooked its flavor is less pronounced than that of salsify, but it has an agreeable flavor and is worthy of attention in this country. It can be dug and stored in the fall or harvested as needed during the winter and spring. The leaves of this plant are prickly and somewhat unpleasant to handle on this account.

TURNIP

The turnip (*Brassica rapa*) is not of great commercial importance, but is grown by a large percentage of home gardeners. While the turnip is one of the minor crops, it is grown on a small scale by large numbers of market gardeners in nearly all parts of the United States. It is a cool-season crop, grown mainly as a fall crop in the North and as a winter crop in the South; also to some extent as an early spring crop in the North. In the South, the turnip is grown more for the foliage, which is used for greens, than for the enlarged root.

History and Taxonomy.—It is not definitely known where the turnip originated, but it is said to be found growing wild in Russia and Siberia. It has been in cultivation since ancient times and was brought to America at an early period. It was known in Virginia in 1609.

When planted in the spring the turnip is an annual, but when planted later it is a biennial. It belongs to the genus Brassica and the family Cruciferae, and is therefore closely related to the cabbage, cauliflower, rape, kale, etc.

Soil Preferences.—While the turnip is grown on all types of soil, it thrives best on a deep rich loam.

The method of preparation suggested for beets and carrots would be satisfactory for turnips. In fact the turnip is not nearly so exacting in this respect as either beets or carrots since the seeds germinate quickly and the plants make rapid growth.

Manures and Fertilizers.—The manure and fertilizer treatments suggested for beets would be satisfactory for turnips, although beets are usually more heavily fertilized. Turnips do not seem to need so much potash as most of the other root crops, but require as much phosphorus and nitrogen.

Planting.—The turnip is grown almost entirely from seed sown where the crop is to mature. Since it does not thrive in hot weather the seed is planted very early in the spring and in late summer in the North, and during the fall and winter in the South. For the fall crop in the North, the seed should be planted about two months before hard freezes are expected. Seed for the spring crop should be planted as soon as the soil can be prepared.

Turnip seed is generally planted in rows 12 to 15 inches apart for hand cultivation and about 24 inches apart for horse cultivation. Seed drills are used where a considerable area is to be planted and the seed is covered about ½ inch deep. The usual rate of planting is 2 pounds of seed to the acre for hand cultivation and a little less for horse cultivation. Broadcast seeding is not practiced to the extent that it was formerly but when this method is followed more seed is required than under the row method. A comparison of drill and broadcast sowing of seed was made at the Wyoming Experiment Station with results decidedly in favor of planting in rows. Twelve varieties were used in the experiment and the average yield was 60,578.8 pounds for the drilled and 28,429 pounds for broadcast planting. The rows were 30 inches apart and where the seed was sown broadcast it covered a strip 1 foot wide.[1]

Thinning.—After the plants become well established they are thinned to stand 2 to 6 inches apart in the row, the distance depending on the type and purpose for which the crop is grown. If small-growing varieties are grown for bunching, the smaller distance is sufficient while the large varieties require the greater distance, if they are to develop to large size. In the South the thinning continues over a considerable period and the plants removed are used as greens.

Cultivation.—Cultivation is usually given turnips when they are grown in rows, but when the seed is sown broadcast cultivation is impossible. The methods of cultivation suggested for beets are satisfactory for turnips.

Varieties.—The most popular varieties are the Purple Top Globe, White Milan, White Flat Dutch, White Egg, Yellow Globe, and Yellow Aberdeen. The Seven-top is a popular variety in the South where the foliage is used for greens.

Diseases and Insects.—Most of the diseases and insects affecting the turnip are also injurious to cabbage and have been discussed under the latter. Clubroot and black rot are the most serious diseases; turnip aphis, root maggot, and flea beetles are the most injurious insect pests.

Harvesting.—Turnips are harvested in the same manner as beets. For use as greens, the plants are thinned and the foliage is cooked in the same way as kale. Young turnips are often bunched as described for beets, but a large part of the crop is harvested in the fall and the tops are cut off as they are pulled. The turnips are then packed for market or are stored. The methods of storage are the same as for the other root crops.

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[1] See *Wyoming Bull.* 22, 1894.

* RUTABAGA

The rutabaga (*Brassica Napobrassica*) is similar in general appearance to the turnip, but differs from it in having a denser root, which is usually rounded or elongated instead of being flattened; the leaves are smooth and covered with a bluish bloom whereas the leaves of turnip are hairy and green. The roots arise from the underside of the enlarged root as well as from the taproot in the rutabaga and the crown is long and leafy as compared to the turnip.

The culture is practically the same as that given the turnip, except that it requires 4 to 6 weeks longer to mature and grows to greater size than most varieties of turnips.

The rutabaga is grown commercially to a greater extent in Canada than in the United States. Under some conditions in parts of Canada, the plants produce seedstalks before the roots reach marketable size; this results in loss. Peto (1934) reported results that indicate that exposure to relatively low temperature (50°–55°F.) is an important factor in bolting.

In parts of the United States and Canada, as well as in some parts of Europe, a physiological disease known as brown heart, mottled heart, or raan has caused considerable loss. Results of experiments by many experimenters, including O'Brien and Dennis (1935 and 1936), MacLeod and Howatt (1935), and many others, have shown that this trouble results from a deficiency of boron and that it can be cured by applying from 10 to 30 pounds of commercial borax to the acre.

* RADISH

The radish is a favorite crop of the home gardener because it is easily grown and is ready for use in 3 to 6 weeks from time of seed sowing. Commercially, it is grown to a limited extent by a large percentage of market gardeners, by many greenhouse vegetable growers, and by truck growers in a few localities, especially in California, Mississippi, and a few other southern states.

The radish is probably a native of Europe and Asia. It has been in cultivation for a very long time, being highly prized by the Egyptians at the time of the Pharaohs, and was also known and highly prized by the ancient Greeks.

The radish (*Raphanus sativus* Linn.) is both annual and biennial, and belongs to the Cruciferae or mustard family. It is related to the cabbage, mustard, etc., but does not belong to the same genus.

Soil Preferences.—The radish is grown on all types of soils, but a light, friable soil is considered best. Since it requires only a short time to grow a crop of the varieties commonly used in America, it can be produced on types of soil that are not satisfactory for other root crops. For an early crop, sandy or sandy-loam soils are preferred but for summer radishes a cool, moist soil gives better results.

The preparation of the soil should be about the same as described for beets and other root crops.

Manures and Fertilizers.—Since this crop is grown largely in early spring, or in winter, some readily available fertilizer should be used. In addition to commercial fertilizer, well-rotted manure is often used in large quantities, but fresh manure should never be used immediately before planting.

Planting.—The radish is hardy and the first planting is therefore made very early in the spring in the North and during the winter in the South. For a succession of crisp, tender roots several plantings should be made at intervals of about 10 days. By the proper selection of varieties, radishes may be had throughout the season and even during the winter since the winter varieties can be kept in storage. However, most of the radishes grown in this country are the quick-maturing varieties, which do not thrive well in hot weather.

It is often grown as an intercrop, or companion crop, and is planted between the rows of other vegetables, so that the spacing is determined to a considerable extent by the distance allowed the other crop or crops. When planted alone, the rows are spaced about 12 to 15 inches apart requiring 10 to 12 pounds of seed to the acre. The seed is sown by hand for small plantings in the home garden and with seed drills in commercial gardens. It is sown rather thickly and the plants thinned after they become established. The first thinning leaves the plants ½ to 1 inch apart for the small varieties; then the larger ones are pulled as soon as they reach edible size. Large-growing varieties, especially those known as "winter radishes," are thinned to stand 2 to 4 inches apart in the row.

Varieties.—Varieties of radishes are divided into classes with reference to the season of the year in which the crop is grown, and with reference to the shape of the root. The former system has the advantage of bringing together those varieties planted at the same time, but it does not aid in identifying them.

For practical purposes grouping of varieties with reference to the season in which the crop is grown is most satisfactory. They are classed as spring, summer, and winter varieties. Of the spring varieties, the most popular globular roots are Scarlet Turnip, Scarlet Turnip White Tipped, Scarlet Globe, Rapid Red, Ne Plus Ultra, and White Box; the best known olive-shaped spring radish is the French Breakfast. The long-rooted spring varieties are represented by Cincinnati Market, Icicle or White

Icicle, Long Scarlet Short Top, and Chartier. Of the summer varieties Strasburg, White Vienna, Golden Globe, Stuttgart, and Chartier are well known. All of these except the Golden Globe have long roots. Among the winter varieties are White Chinese, China Rose, Long Black Spanish, Round Black Spanish, and Sakurajima. The Sakurajima grows to enormous size and has solid, firm flesh of good flavor.

Insects.—The insects most commonly attacking radish are plant lice, cabbage-root maggot, and flea beetles. Plant lice can be controlled by one of the tobacco sprays, to which soap has been added as a sticker. Dusting with nicotine dust as described for the cabbage aphis would probably be effective. The maggot can be kept in check by screening the bed, but this is impracticable except on a very small scale. Corrosive sublimate solution applied in a stream along the row also aids in keeping the maggot under control. Two applications should be sufficient. Keeping the plants covered with Bordeaux mixture will protect them against the flea beetle, but the treatment stunts the plants and so is not practicable.

Harvesting and Marketing.—Harvesting usually begins as soon as the roots reach edible size. The quick-maturing, spring varieties become strong and pithy if not harvested soon after they reach edible size. The summer varieties remain edible much longer than the spring varieties. The winter varieties remain edible for several months if stored properly.

Radishes are usually pulled by hand and are tied in bunches of 6 to 12 for the smaller-growing varieties and 3 to 6 for the larger varieties. After being bunched, they are usually washed to remove the soil and to give them a fresh, bright appearance. When shipped to distant markets the bunches are packed in baskets, hampers, or crates. For long-distance shipping, ice is usually put in the package as described for spinach. Winter radishes are handled in much the same way as turnips, the tops being removed before the roots are put in storage.

HORSE-RADISH

Horse-radish is found in many farm gardens where it is allowed to grow along the fences or walks. Commercially it is grown principally in Missouri (in the vicinity of St. Louis), Illinois, New York, and New Jersey. Missouri produced over one-third of the commercial product in 1919.

Horse-radish is indigenous to eastern Europe and is now spontaneous in the United States. Both leaves and roots were used as food in Germany during the Middle Ages. Prior to the sixteenth century, it was probably grown for medicinal purposes only.

It belongs to the Cruciferae or mustard family and is known as *Armoracia rusticana*. It is a hardy perennial that produces a tuft of large leaves similar in appearance to the leaves of dock. The flower stem grows to a height of 2 to 3 feet and bears small white flowers in panicled racemes. Seed is produced, but it seldom matures and is never used for propagation.

Soil.—A deep, rich, moist, loamy soil is desired for growing horseradish. On hard soil the roots become much branched and crooked. In the vicinity of St. Louis a rich river-bottom soil is used.

In the preparation, the soil should be deeply plowed and thoroughly pulverized so that long straight roots can be grown.

Manures and Fertilizers.—Unless the soil is already rich and in good physical condition it should be heavily manured, preferably with well-rotted manure. Some commercial fertilizer is often applied in addition to a heavy coating of manure. A fertilizer containing about 50 pounds each of nitrogen and potash and 75 to 100 pounds of phosphoric acid should be sufficient. Where no manure is used, the fertilizer should supply at least 100 pounds of each of the three important ingredients.

Planting.—The plant is propagated from root cuttings made from the side roots which are trimmed off in preparing the roots for market. These vary in size from 1/4 to 1/2 inch in diameter and from 2 to 8 inches in length. The long cuttings are best. As these roots are nearly uniform in diameter throughout their length, they are cut off square at the top and oblique at the lower end to denote which end is to be planted up. They are then tied in bundles, packed in sand, and stored in a cool, moist place until spring. The cuttings may be planted in a deep furrow made with a large plow, or a dibble may be used to make holes for them. In either case the cuttings are set in a slanting position with the square end up and about 3 or 4 inches below the surface of the soil. The soil should be well packed around the cuttings. The distance of planting is about 10 to 15 inches apart in the row with the rows 3 to 4 feet apart. Planting is usually done early in the spring so as to give the crop a full growing season.

Cultivation and Care.—The crop makes most rapid growth during the latter part of the summer; therefore, thorough cultivation should be given throughout the growing season.

In order to secure large, straight roots some growers remove the side roots early in the season. This is done by removing the soil and stripping off the side roots from the upper part of the main root. The soil is then replaced. This treatment results in the production of large, compact roots, but unless the work is carefully done serious injury may follow. The earlier in the season the trimming is done the less check there is to growth. It is claimed by some that a larger yield is obtained when the roots are trimmed than when they are allowed to grow without being disturbed. Certainly trimming results in a large percentage of straight roots of good size.

Harvesting.—The roots are hardy and may be left in the ground all winter, but it is better to dig them in the fall and store them so that they will be available when wanted. The roots are plowed out, the tops and side roots removed, and the marketable product sold or stored. Since the horse-radish is likely to become a bad weed it is important to remove all the roots in harvesting. The roots are washed and packed in barrels for shipping to market. For special trade they are sometimes tied in bunches of 6 or 8 roots. Only the large, straight roots bring a good price.

The roots are stored in a cool, moist cellar or storage house. Care should be taken to prevent the roots from becoming withered.

TURNIP-ROOTED CHERVIL

Turnip-rooted chervil (*Chaerophyllum bulbosum* Linn.) is a small-rooted plant, native of Europe and Asia. It is a biennial, belonging to the Umbelliferae family, and is of recent culture. The root is swollen, much like a short carrot but smaller, dark gray in color with yellowish-white flesh.

In Europe the seed is usually sown in autumn since it does not germinate well if kept over winter in the ordinary manner. Spring planting may be followed if care is taken to stratify the seed in sand. If this is done the seeds germinate immediately after they are sown. The crop gets its growth in a relatively short time, but it improves in quality if left in the ground after the leaves wither and die. The roots may be taken up and stored if the land is needed for another crop. They keep well through the winter if properly stored.

The roots are eaten boiled and have a sweet, aromatic flavor. This plant is little known in America.

SKIRRET

Skirret (*Sium Sisarum* Linn.) is a hardy perennial of the Umbelliferae family, although it is grown as an annual. The plant produces numerous swollen roots, forming a bunch from the crown. The roots are grayish white in color with firm white flesh.

It may be propagated from seeds, offsets, or division of the roots. The seed is often sown in a prepared bed and the seedlings transplanted to the permanent bed when four or five leaves have developed. Plants propagated from offsets, and division of the roots are treated like those raised from seed. Skirret is very hardy and the roots may be left in the ground throughout the winter.

The roots are tender and have a sweet taste. They are used in the same manner as salsify.

CELERIAC

Celeriac, or turnip-rooted celery (*Apium graveolens* Linn. var. *rapaceum* DC.), is grown for its thick, tuberous base, which is used as a salad or as a cooked vegetable. It has the flavor of celery and is popular in Europe but is little grown in America. The plant does not develop so much foliage as celery.

Seed is usually sown in a greenhouse or hotbed for an early crop and in a well-prepared outdoor bed for a late crop. The plants are handled exactly like celery except that they are not blanched since the leaves are not eaten. European seedsmen list several varieties. Giant Prague, Apple, and Early Paris probably are the most popular. In America, the Giant Prague is the most common and many seedsmen list no other variety.

CHAPTER XXI

BULB CROPS

ONION	SHALLOT
LEEK	CIBOL (CIBOULE) OR WELSH ONION
GARLIC	CHIVE

All the bulb crops are hardy. When grown in the South they are usually planted in fall, or in winter and harvested in spring or early summer. The onion is the only member of this group grown to any great extent in this country. The others are grown chiefly for sale in large cities where there is a considerable foreign population.

All of these crops belong to the same genus, Allium, of the family Liliaceae, and their cultural requirements are similar.

ONION

The onion is by far the most important of the bulb crops and is one of the important vegetable crops. It is grown commercially in nearly all parts of the United States. The crop is grown for consumption in the green state and as mature bulbs. The Bermuda type is grown in Texas and in other southern states, the Spanish in California and other western states, and the domestic type of strong flavor is grown in nearly all of the states, but particularly in the North and in California. The onion is one of the important vegetable crops of the United States, the acreage and production of which have increased markedly during recent years as is shown in Table XXXIV. In spite of this increase, the average annual value for the period 1933 to 1937 was considerably below that for the period 1918 to 1922. The lower price received during

TABLE XXXIV.—AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF BULB ONIONS BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield per acre, 100-lb. sacks	Production, sacks (000 omitted)	Price per 100 lb.	Value (000 omitted)
1918–1922	60,470	162	9,824	$1.93	$18,964
1923–1927	68,892	165	11,373	1.70	19,350
1928–1932	84,430	157	13,254	1.23	16,298
1933–1937	93,474	153	14,315	1.07	15,382

recent years probably is due, in part, to the general economic conditions, but it is also true that a relatively small crop brings larger total returns than an abnormally large one. For example, 10,943,000 sacks of 100 pounds of onions in 1925 brought a total of $21,309,000, whereas 13,373,000 sacks brought only $19,096,000 in 1927; 14,471,000 sacks brought $18,618,000 in 1935 and 17,227,000 sacks brought $12,371,000 in 1936.

The 10 leading states in acreage of onions in 1937 were Texas, New York, Michigan, California, Colorado, New Jersey, Massachusetts, Minnesota, Indiana, and Idaho. In 1937, the acreage was much lower than normal in some states, especially in Indiana, Idaho, and Ohio; in other states the acreage was considerably above normal, as in New York. Four states, Texas, New York, Michigan, and California, had over 60 per cent of the total commercial acreage reported. Texas alone accounted for over a quarter of it. Green bunching onions are not included in the estimates given in the table.

History and Taxonomy.—The onion is probably a native of Asia, perhaps from Palestine to India. It has been in cultivation and used as a food from the earliest period of history. It is mentioned in the Bible as one of the things for which the Israelites longed in the wilderness. It is mentioned as being cultivated in America as early as 1629.

The onion belongs to the genus Allium, which contains about 300 species widely distributed in northern temperate regions, biennials and perennials, mostly bulbous. Many species are native to North America. Some of the wild species produce bulbels instead of seed in the flower cluster, as does the tree onion. All but a few of the plants of this genus have the characteristic onion odor and flavor.

Temperature and Photoperiod on Growth.—Garner and Allard (1920) and McClelland (1928) have shown that length of day affects flowering and bulb formation in certain varieties of onions. Garner and Allard found that the Silver Skin variety grown from sets, planted May 19 at Washington, D. C., developed normal bulbs and showed the first blossoms July 14 under the normal length of day. Under a 10-hour day, the plants remained green for 12 months and formed no bulbs and no flowers. McClelland grew Prizetaker, Bermuda White, Yellow Globe Danvers, and Silver King under different lengths of day in Puerto Rico. Prizetaker remained in the green-onion stage for 15 months under a 11-hour day; under a 13.5-hour day bulbs were not formed; under a 15-hour day all had formed bulbs at 30 weeks. Silver King and Yellow Globe Danvers responded about the same to length of day as did the Prizetaker. On the other hand, the Bermuda White developed well-formed bulbs and the tops were dead in 22 weeks under the 13.5-hour length of day.

Magruder and Allard (1937) and Thompson and Smith (1938) have reported results on effects of length of day on bulbing similar to those of Garner and Allard and of McClelland, but Thompson and Smith have shown that relatively high temperature, as well as a long photoperiod, is essential for bulb formation in certain varieties of onions that are commonly grown under long-day conditions. Figure 50 shows the effect of temperature on bulb formation of plants grown under a long day (about 15 hours). Garner and Allard, McClelland, and Magruder and Allard did not study the temperature factor.

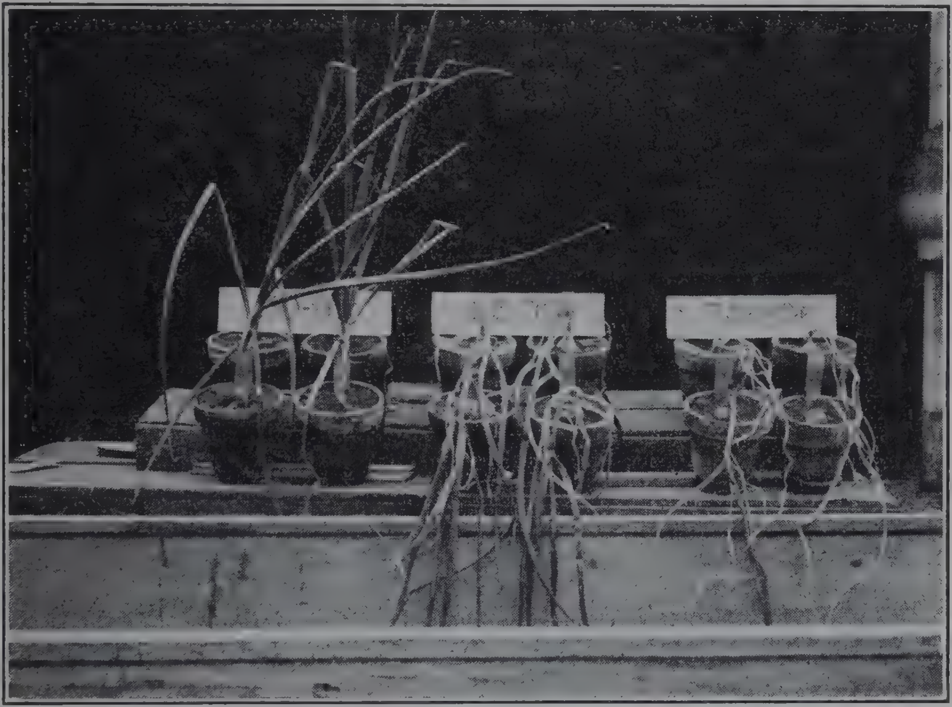

Fig. 50.—Effect of temperature on bulb development in the Ebenezer variety of onion grown under long photoperiod. Left to right; 50° to 60°, 60° to 70°, and 70° to 80°F. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Thompson and Smith have shown also that temperature is more important than length of day in seedstalk development. At relatively low temperature (50° to 60°F.) under a short day (9 to 12 hours) onion plants went to seed readily, while under high temperature (70° to 80°F.) they did not go to seed under either a short day or a 15-hour day. Table XXXV gives the results of one experiment out of several conducted.

Results of the various studies mentioned explain why many varieties of onions do not produce a satisfactory crop when grown in the South during the winter and early spring. These varieties have been developed in regions where they are grown during the long days of summer when the temperature is relatively high. Bermuda onions, on the other hand, were developed in regions where the relative length of day and night varies but little and are now grown as a commercial crop during the relatively short days of fall, winter, and early spring.

Soil Preferences.—Onions are grown on nearly all types of soils from the sandy loams and mucks to heavy clays. The clays are not satisfactory unless well supplied with humus to lighten them. The greatest difficulty encountered in growing onions on clay is the tendency of this type of soil to run together and bake after hard rains. This is especially injurious after the seed has been sown and before the plants have attained sufficient size to permit of cultivation. Sandy-loam soils, when well supplied with humus and heavily fertilized, are satisfactory for onion growing, especially for the early crop. Silty and silty-loam soils are used in growing Bermuda onions in Texas and the common onion in Massachusetts. These are rich and quite satisfactory, especially when there is a considerable quantity of sand present. Muck soils are considered the very best type for the production of bulb onions in the North. A very large part of the dry-bulb crop grown in New York, Ohio, Indiana, Michigan, and California is produced on muck. Since muck soils are almost ideal in texture, they are easily prepared and cultivated. They are organic in nature, rich in nitrogen, and have a high water-holding capacity.

TABLE XXXV.—EFFECT OF TEMPERATURE AND LENGTH OF EXPOSURE TO LIGHT ON SEED-STALK DEVELOPMENT IN ONION PLANTS

Treatment	Red Wethersfield			Ebenezer		
	Number of sets	Number of sets producing seedstalks	Number of seedstalks	Number of sets	Number of sets producing seedstalks	Number of seedstalks
50° to 60°, normal day	20	20	26	20	20	33
50° to 60°, long day	20	20	30	20	20	25
60° to 70°, normal day	20	0	0	19	2	2
60° to 70°, long day	20	2	2	17	1	1
70° to 80°, normal day	20	0	0	20	0	0
70° to 80°, long day	20	0	0	20	0	0

The onion plant is sensitive to high acidity and when grown on a mineral soil more acid than pH 5.6 it is desirable to use lime. Most authorities recommend a soil reaction of pH 6.0 to pH 6.5. On some soils there is a disadvantage in decreasing the acidity beyond pH 6.7 or pH 6.8 because of the danger of rendering some essential element unavailable.

Soils for onion production should be thoroughly prepared. The seedbed should be thoroughly pulverized and have a smooth surface. It is a common practice to drag or roll the land just prior to planting; this is especially important for muck soils.

Manures and Fertilizers.—Manure is important in growing onions on mineral soils, especially those poor in humus, but on muck soils the humus is not necessary and nitrogen, phosphorus, and potash can be supplied more economically in chemical fertilizers. Where manure is used, it is advisable to apply it to the crop preceding onions, especially if it is not well rotted. Fresh manure usually contains weed seeds and, unless plowed under, interferes with planting and cultivating. An application of 15 to 20 tons of manure per acre should be sufficient. Fresh manure should be turned under in the fall, or as early in the spring as possible. On most soils it is advisable to use commercial fertilizer in addition to manure. For silt-loam and clay-loam soils that are well manured, an application of fertilizer supplying 50 pounds each of nitrogen and potash and 100 pounds of phosphoric acid should give good results. On sandy and sandy loams, both the nitrogen and the potash should be increased. Where no manure is used, 75 pounds each of nitrogen and potash and 150 pounds of phosphoric acid is suggested. On sandy and sandy-loam soils without manure, 100 pounds of each of the three important nutrients is recommended, although Hawthorne (1936) reports greater response to phosphorus than to either of the other elements on Webb fine sandy loam in southern Texas. This soil is, however, richer than most sandy-loam soils found in humid regions. Hawthorne recommends 600 to 900 pounds of a 6–12–0 fertilizer.

Fertilizer requirements vary with the type of muck, the length of time it has been under cultivation, the previous treatments, the drainage, and the reaction of the soil. In general, poorly drained and strongly acid mucks require more nitrogen than well-drained, slightly-acid, neutral, or alkaline mucks. Newly cleared muck soils usually require less nitrogen and more phosphoric acid and potash than similar soils that have been under cultivation and well fertilized for several years.

On muck soils used for onions, potash is the main limiting element and growers in some regions limit their fertilizer application to this element. Some phosphorus is needed on all mucks and nitrogen usually is needed on highly acid mucks and those that have been in cultivation many years. Fertilizer recommendations differ considerably in the various states. Knott (1930) recommends for recently cleared muck in New York from no nitrogen to 45 pounds of nitrogen, depending on the type of muck, 150 to 180 pounds of phosphoric acid, and 200 to 275 pounds of potash. For mucks that have been cleared and well fertilized for 10 years or more, Knott recommends about 50 pounds of nitrogen and 100 pounds each of phosphoric acid and potash. Fertilizers recommended for onions on muck soils in Ohio, Indiana, and Michigan supply, in general, twice as much potash as phosphoric acid; for example, a 2–8–16 or 3–9–18 except where drainage is only fair or on muck less than 2 feet deep. Under the latter conditions, an analysis such as a 3–12–15 is suggested. The rates of application are from 1000 to 1500 pounds to the acre. Harmer (1932) states that after the muck has been well fertilized for 2 or 3 years and a reserve has been built up, the application might be reduced. Harmer suggests that the greatest need for nitrogen is with early planted onions, or where the water table is high.

Certain areas of muck soil produce onion bulbs of poor color and with thin scales. The outer scales come off in handling, and this gives the onions a poor appearance and renders them more subject to injury from bruising. Results of studies by Knott (1933) indicate that poor color results from deficiency of copper. Applications of 200 to 300 pounds to the acre of powdered copper sulphate are recommended. The effect of the application lasts for several years and no additional copper is required until the onion bulbs show the need of it. Copper is recommended only where the onions develop poor color and thin outer scales.

Propagation.—The onion is propagated by seed sown where the crop is to mature; by seed sown in a greenhouse, hotbed, or outdoor seedbed; by sets grown from seed sown the year previous; by top sets, which are produced in the flower cluster of the Egyptian or tree onion; and by bottom sets in the multiplier or potato onion. The multiplier seldom produces flowers and seeds. The small bulb or set grows into a large one which again breaks up into small ones.

A large part of the dry bulb onion crop produced in the United States is grown from seed sown where the crop is to mature. In the South this method is not used because the onions mature before they reach marketable size.

Seedlings are used to a large extent for the production of Bermuda onions in Texas and, to some extent, for the production of the Spanish onion in some regions. In southern Texas, seed is planted in outdoor seedbeds in the latter part of September or early in October, using at the rate of 20 to 30 pounds to the acre of bed. Hawthorne (1938) states that 17 pounds of seed per acre of seedbed provided sufficient plants to set 10 acres in rows 14 inches apart and resulted in 45 to 50 per cent of medium-sized plants. Transplanting gave better results than direct field sowing in Hawthorne's experiments.

Sets are used for the production of green bunching onions; for the production of an early crop of dry bulbs for market in the North; to a considerable extent, for bulbs for home use in nearly all sections of the country; and in growing common varieties for home use and for market in the South. Sets usually produce a larger yield than seeds on ordinary upland soil, but on muck soil it is doubtful if this is true. Lloyd (1914) reported results of experiments conducted at the Illinois Experiment Station on a brown silt-loam soil. In these experiments yields from seeds and sets were compared for Yellow Globe and Prizetaker varieties covering a period of 6 years. A summary of the results from these experiments is given in Table XXXVI.

TABLE XXXVI.—COMPARISON OF YIELDS, TIME REQUIRED TO MATURE, AND COST OF GROWING FROM SEEDS AND SETS OF TWO VARIETIES OF ONIONS
(Data from Ill. *Bull.* 175)

Variety	Yield per acre, bu.		Number days to mature		Cost of growing per acre	
	Seed	Sets	Seed	Sets	Seeds	Sets
Yellow globe...	345.74	459.02	137	112	$101.77	$154.69
Prizetaker*.....	373.47	610.99	137	114	107.17	126.31

* Prizetaker comparison for 3 years only.

The cost of growing an acre of onions was greater from sets than from seeds, due to the increased cost of the sets themselves. The labor for growing the crop was 328.60 hours for seed and 303.49 hours for sets. The greater amount of labor required for onions grown from seed was largely in the tillage, in weeding, and in thinning. The gross returns and profits were greater from the onions grown from sets due to the larger yield and higher price received. The higher price was due to earlier maturity and to the greater percentage of large onions.

Planting.—The best time for planting depends on the locality, the type of onions, and the method of propagation used. In the North, sets for green onions or for dry bulbs are usually planted as early in the spring as the soil can be prepared, since light freezes do not injure them. When the multiplier onion is used, the sets are usually planted in the fall. Seeds of the common onion, when planted where the crop is to mature, are sown as soon as hard frosts are over in the spring in regions where severe freezes occur. In the South the onion is grown during the winter and seeds, sets, and seedlings are planted in fall or winter depending on the locality and the type of onion. In parts of Texas, seed is sown direct in the field in September or October; where seedlings are used they are set in the field during the latter part of November or early in December. Planting of seedlings is done mainly by hand, and the plants are spaced about 4 inches apart in rows 14 to 16 inches apart. It is the usual practice to trim the roots and tops before the plants are set in the field. Results of experiments by Hawthorne covering a period of 5 years showed a slightly larger yield for unpruned plants over severely pruned plants, but the unpruned are a little more difficult to plant.

Early planting is important in all regions where the crop is grown during the hot weather and long days of summer because there is a tendency for the onion to mature about a certain time, regardless of the time of planting, within limits of 5 or 6 weeks in spring. Lloyd (1914) showed that a spread of 6 weeks in time of planting had a marked effect on yield but much less effect on time of maturity. The early plantings produced the largest total yield as well as the largest proportion of large bulbs.

Methods of planting are very much the same in the various regions. Seed is sown with a drill when the crop is grown commercially and 4 to 6 pounds is used to the acre if sown where the onions are to mature. Gang planters that sow four or more rows at a time are often used for large acreages. These are drawn by a horse or by a small tractor. Onion sets are planted by hand or with a machine which opens the row, drops the sets, and covers them with soil. To do satisfactory planting with a machine, it is necessary to grade the sets into about three sizes. At the distances ordinarily used, 15 to 30 bushels of sets are required to plant an acre, the quantity depending on the size of the sets. The larger the sets, the greater the quantity required to plant an acre of land. If onion sets were true spheres, it would take eight times as many bushels of sets 1 inch in diameter as of sets ½ inch in diameter to plant an acre of land, the spacing being the same. Beaumont *et al* (1935) give data on the number of bushels of sets of three sizes to set an acre as follows:

	Size, in.	Weight, grams	Yield, bu. per acre
Large	¾ to 1	6.3	94.98
Medium	½ to ¾	1.4	25.08
Small	¼ to ½	0.5	8.18

Thinning.—The practice of sowing onion seed thickly and then thinning the seedlings to the desired distance was commonly practiced many years ago. At the present the tendency is to sow the seed more thinly and dispense with thinning since this is an expensive operation. Results of experiments on a brown silt-loam soil in Illinois show that thinning does not pay under average conditions. Table XXXVII gives the results of these experiments covering 4 years 1908, 1909, 1911, and 1912.

The figures in Table XXXVII show that the total yield of onions was greater in the unthinned plot and while the percentage of large bulbs was greater on the thinned plot the actual yield of these bulbs was nearly the same on the two plots.

On muck soil, thinning is of less importance than on mineral soils since muck is very light and there is no danger of producing deformed bulbs even where they are crowded. Large yields are obtained where the onions are grown thickly and since large size is of no importance for common onions, thinning is seldom justified.

Cultivation and Weeding.—To produce a good crop of onions, it is essential that weeds be kept under control. This is of special importance during the early growth of the onion as the plant grows slowly at first and is readily injured by weeds. Experimental evidence reported by Thompson, Wessels, and Mills (1931) shows the importance of weed control but no very marked benefit from the maintenance of a soil mulch.

TABLE XXXVII.—COMPARISON OF YIELDS AND COST OF GROWING ONIONS THINNED AND NOT THINNED
Data from Ill. *Bull.* 175

	Average yield, bu. per acre			Average cost of growing and harvesting per acre*
	Total	Large	Small	
Thinned	338.34	308.13	30.20	$52.89
Not thinned	396.83	309.89	86.94	45.23

* Figures include cost of weeding, thinning and harvesting only since cost of planting and cultivating were the same.

Eliminating cultivation after the tops began to fall over did not result in a decrease in yield, but resulted in considerable saving of labor. The onion plant has a relatively sparse and poorly distributed root system as shown in Fig. 51.

Cultivation usually begins as soon as the plants appear above the surface of the soil and continues until the tops seriously interfere with the work. Hand cultivation, with shove hoes, wheel hoes, and onion weeders, is practiced to a very large extent. Onion weeders are used by some growers to help keep the weeds under control between the plants in the rows. These are quite satisfactory on very light soils when the plants are small but after the tops have straightened up. If they are used before, many of the plants are pulled out. To do good work, weeders must be used when the weeds are very small and before a hard crust is formed on the soil. Some growers have tried weeders and discarded them on account of apparent injury to the plants and unsatisfactory weed control. In many cases the injury was not so serious as it appeared immediately after the weeder was used. In other instances the weeds were allowed to get too large before the weeder was used. Judicious use of the weeder on a loose soil will reduce the expense of hand weeding. Cultivation between the rows is practiced to keep down weeds and to maintain a surface mulch. For weed destruction shove hoes and the blade attachments of wheel hoes are more satisfactory than the teeth or shovel attachments used on hand cultivators.

Hand weeding is the most laborious and most expensive operation connected with growing the crop. Even where the onion weeder is used hand weeding is necessary. This is often done by women and children who crawl along the rows and remove all the weeds between the plants. In wet weather it is necessary to remove the weeds from the field to prevent their taking root again. In a study of onion growing in Massachusetts it was found[1] that it required on an average 21 days' labor per acre to weed onions. In addition 5 days were required for cultivating and 4 days for shove hoeing.

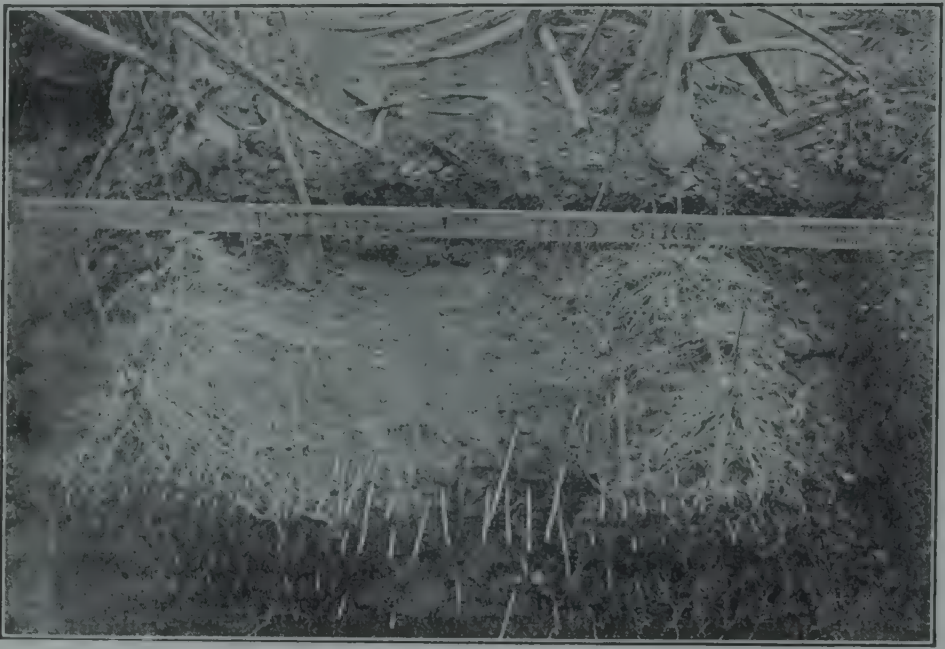

FIG. 51.—Roots of onion uncovered by washing off the surface soil to the depth of 2 to 3 inches. *(Courtesy of Cornell Univ. Agr. Exp. Sta.)*

Varieties.—There are two general types of onions grown in America for use as dry bulbs. They are usually designated as the "American" and the "foreign" or "European" types. In general the American onions produce bulbs of smaller size, denser texture, stronger flavor, and better keeping quality. Three distinct colors are recognized, red, white, and yellow. Probably 75 per cent of the bulb crop consists of yellow varieties. Onions vary in shape from oblate to globular, the latter being preferred on the market. The most important varieties of yellow onions are Yellow Globe, Yellow Globe Danvers, Danvers, Japanese or Ebenezer, Southport Yellow Globe, and Ohio Yellow Globe (Fig. 52). Of the red varieties, Southport Red Globe and Red Wethersfield are the best

[1] *Mass. Bull.* 169.

known. Southport White Globe, White Pearl, Silverskin, and White Queen are the most popular white varieties.

Of the foreign onions the Bermuda is the most popular, thousands of acres of land being devoted to this crop in Texas. Yellow Bermuda, Crystal White Wax, and Red Bermuda are the varieties grown. By far the largest acreage of this variety is of the Yellow Bermuda. Spanish or Sweet Spanish (Denia, Valencia) is a mild type of onion grown in some of the western states. It is globular in shape and grows to large size. Prizetaker is similar to the Spanish, but is a little stronger in flavor. Another type of onion that has become popular in recent years is a mild-flavored red onion imported from Italy and grown to some extent in California. This onion is known as Italian Red or Red Italian, although there are several names given to varieties or strains of this general type. A type of onion grown in the vicinity of New Orleans, known as Creole, probably belongs to the "foreign" group.

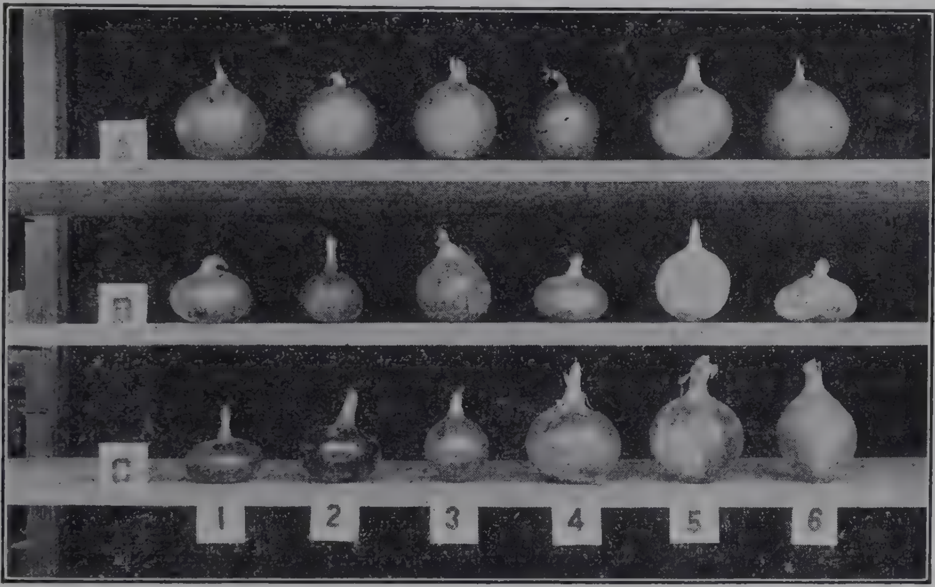

Fig. 52.—Varieties of onions. *A*, 1 and 2, Yellow Globe Danvers; *A*, 3, 4 and 5, Southport Yellow Globe; *A*, 6, Ohio Yellow Globe; *B*, 1, Yellow Danvers; *B*, 2 and 3, Australian Brown; *B*, 4, Ebenezer; *B*, 5, Southport White Globe; *B*, 6, White Portugal; *C*, 1, Early Flat Red; *C*, 2, Red Wethersfield; *C*, 3, California Early Red; *C*, 4, Prizetaker; *C*, 5, Denia or Spanish; *C*, 6, Giant Gibraltar. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

In addition to the varieties and types mentioned, White Multiplier, Yellow Multiplier (potato onion), and the Egyptian or Perennial Tree onion are grown for early bunching onions. These are very hardy.

Diseases and Insects.—The onion is attacked by many diseases, the most important being smut, downy mildew, pink root, and neck rot, although some others often cause considerable losses. The only insects that are injurious to onions in most regions are onion thrips and onion maggots.

Onion Smut.—Onion smut (*Urocystes cepulae*) is probably the most destructive disease of onions grown in the North. It has not been found in the onion-growing sections of Louisiana and Texas and is of little consequence elsewhere in the South. Losses from smut are confined largely to onions grown from seed. When seedlings are used the injury is confined to the seedbed; when dry sets are employed the smut does not attack the plants. The loss is due to killing the young plants, resulting in thin stands.

Walker and Jones (1921) have shown that the smut fungus will grow at temperatures too low for good growth of the onion plant, but that a soil temperature of 85°F. will inhibit the growth. The optimum temperature for infection is about 72°F. It is thought that the high temperature prevailing in the onion-growing sections of the South during the early growth of the plants accounts for the fact that smut is not a factor there.

Since sets are immune to smut, it is possible to eliminate losses by planting sets instead of seeds. Formaldehyde solution applied in the furrow back of the seed at the time of sowing has given good control. The strength of solution varies between 1 gallon of formaldehyde to 65 gallons of water and 1 gallon to 100 gallons of water depending on the moisture in the soil. On very moist muck soil, the stronger solution is advised, while on dry muck the weaker solution is recommended. In most cases 1 gallon of formaldehyde to about 75 gallons of water gives good results. The solution is applied in a small stream through a tube connected with a tank carried on the seed drill. The outlet tube should have an inside diameter of, at least, $\frac{5}{16}$ inch and be supplied with a stopcock which may be opened or closed by manipulating a wire extending to the handle of the seeder.

Onion Mildew.—Mildew (*Peronospora schleideniana*) may be recognized by the fungus coating on the outer surface of affected leaves. Affected plants turn yellow and finally die. The disease usually appears at a few points in the field and spreads under favorable conditions of moisture.

The pathogen overwinters most commonly as dormant, vegetative mycelium inside and near the bases of the bulbs of top-set, multiplier, or winter onions. Many hundreds of plantings of these onions occur in farm and village gardens, over half of which have been found to be perennially diseased in recent surveys in New York. There is some evidence that the fungus can also live over within the bulbs of several kinds of onions held in storage and perhaps sometimes within the seed, as well as by means of resting spores in old diseased leaves which drop to the ground. But these methods are not believed to be of great importance in America. Spraying or dusting has not proved economical.

Some authorities, notably Newhall (1938 and 1939), believe that removal of all perennial onions would eliminate most of the danger from mildew because spores arising from them in the spring are wind borne. Plantings of set onions usually contract mildew weeks before those grown from seeds and therefore should not be grown near the latter.

PINK ROOT.—This disease is caused by *Fusarium malli* and is present in many onion-growing sections of the United States and Canada, and is said to be very destructive in Bermuda. The roots of affected plants turn pink, shrivel, and die. The bulb continues to produce new roots and this depletes it of the food supply so that it fails to reach marketable size.

After the soil once becomes infected it is not possible to lessen the infection. Keeping the plants growing rapidly by good fertilization and good cultivation to control weeds will enable them to overcome the injury to some extent. The disease is most serious in dry, hot weather during the time the bulbs are forming.

NECK ROT.—The neck rot (*Botrytis alii*) is a disease of mature bulbs and sets, and is found in all regions where onions are stored. Under poor storage conditions losses are often heavy. The disease seldom occurs on the bulbs while they are in the ground, although the fungus may attack injured leaves. The lesions on the bulbs appear as sunken dried areas about the neck, but may involve the whole bulb. The fungus lives over winter by means of sclerotia, and as mycelium in the decaying onion.

Since this is a storage trouble, care should be exercised to have the onions well matured and well cured before storing. Thick-neck onions should be discarded since these are slow to cure and succumb quickly to the disease. Onions should be stored in slatted crates, so piled that air can circulate all around them. The temperature should be kept as near 32°F. as possible and the humidity low.

ONION THRIPS.—Onion thrips (*Thrips tabaci*) are small, yellowish, sucking insects which attack the leaves of onion plants giving them a blanched appearance. The tender, center leaves become curled and deformed and the outer leaves turn brown at the tips. Thrips are most injurious during dry weather and are seldom very destructive during rainy periods, since the rain knocks many of them off and kills them.

Experiments with naphthalene dust, according to Crosby, Chupp, and Leiby (1938), have shown that thrips can be controlled and the yields of onions materially increased by its use. They suggest 40 pounds of naphthalene to 60 pounds of hydrated lime, mixed together, and allowed to stand in a tight container for at least 24 hours. The crude naphthalene should be crushed and sifted through a 50-mesh screen. This mixture is applied at the rate of 200 pounds to the acre with a rotary hand duster or a power duster. The dust should be directed into the crown of the plants. The first application should be made as soon as injury becomes apparent, and other applications at intervals of a week as long as thrips injury justifies the expense.

ONION MAGGOT.—The onion maggot (*Hylemyia antiqua*) is the larva of a small fly resembling the common house fly, but smaller. Eggs are laid on the plants near the base or in cracks of the soil. The small maggots, about ⅓ inch long, kill the young plants and later burrow into the bulbs, causing decay.

The most satisfactory method of controlling the maggot is by spraying with a 2 per cent lubricating-oil emulsion. Red engine oil and paraffin lubricating oil have been used and both are satisfactory. Oil emulsion can be purchased ready for use after dilution and, for the small grower, this may be the most satisfactory. Large growers or a group of growers can make some savings by buying the materials and making the emulsion. It may be diluted with Bordeaux mixture or with water, but Bordeaux has given the most satisfactory results.

In spraying for this maggot, the solution should be applied to moisten the soil around the base of the plant. The first application should be made when the adult flies appear; additional applications are needed at intervals of a week or 10 days. Usually three applications are sufficient.

Premature Seeding.—In regions where onion sets are used for growing onions and in Texas, where plants are grown during the winter, it is common for seedstalks to develop before the bulb reaches marketable size. In some years this premature seeding results in large losses because most of the plants that produce seedstalks fail to develop marketable bulbs.

Premature seeding has been attributed to many factors such as the use of large sets, to unfavorable storage conditions under which the sets had been kept prior to planting, and to unfavorable weather during the growth of the onion crop; especially to conditions that result in checking growth. Results of experiments reported by Boswell (1923) and by Thompson and Smith (1938) show clearly that size of sets and storage temperature are very important. Boswell showed that sets stored at 50°F. produced a larger percentage of seeders than similar sets stored at 32°F., and that the larger the sets the greater was the percentage of seedstalks. Table XXXVIII gives the results of experiments, reported by Thompson and Smith, on the effect of size of sets and storage temperature on premature seeding of three varieties of onions.

A glance at Table XXXVIII will show that large sets produced a much larger percentage of seedstalks than did either the medium or the small. The storage temperature that resulted in the highest percentage of seeding was 40°F. and 50°F. was next. The 60° to 70°F. range of temperature was less favorable to seedstalk development than was the

30° or 32°F. temperature, but the high temperature was not satisfactory because of shriveling and sprouting in storage. The best storage temperatures used were 30°F. and 32°F. The Ebenezer sets produced a smaller percentage of seedstalks than did the other varieties.

The largest yield of marketable bulbs was produced by sets that had been stored at temperatures least favorable for subsequent seeding. Small sets produced a lower yield than the medium in every comparison, and a lower yield than the large, with the exception of the sets stored at 40° and 50°F.

If the sets were stored at 30° or 32°F. and then all sets over an inch in diameter were discarded, the loss from premature seeding would not be serious. Sets less than ½ inch in diameter ordinarily will not produce so large a yield as will those from ½ to 1 inch in diameter.

TABLE XXXVIII.—AVERAGE PERCENTAGE OF SEEDSTALKS DEVELOPED FROM LARGE, MEDIUM, AND SMALL SETS OF THREE VARIETIES OF ONIONS AFTER BEING STORED AT VARIOUS TEMPERATURES

Variety and size	30°F.	32°F.	40°F.	50°F.	60° to 70°F.
Ebenezer, Large	2.20	9.14	40.98	35.02	1.58
Ebenezer, Medium	0.18	0.34	2.05	1.33	0.08
Ebenezer, Small	0.00	0.00	0.00	0.06	0.08
Yellow Globe, Large	33.37	42.72	79.98	68.64	18.51
Yellow Globe, Medium	4.69	4.88	21.58	14.07	2.70
Yellow Globe, Small	0.11	0.00	1.28	0.88	0.08
Red Wethersfield, Large	40.36	68.10	84.38	78.86	24.58
Red Wethersfield, Medium	8 25	9.72	26.60	20.56	6.25
Red Wethersfield, Small	0.10	0.37	1.13	0.30	0.29

Hawthorne (1938) has shown that large seedlings are much more likely to develop seedstalks than are the small or medium ones grown under the same conditions.

Harvesting.—Onions for use in the green stage are harvested as soon as they reach edible size. It is a common practice to make several pullings, removing the largest plants each time and leaving the others to develop. The plants are pulled by hand, the roots trimmed and the outside skin peeled off, leaving the stem clean and white. The onions are then tied in small bunches, the number depending on the size and on the local custom. Green bunching onions are not shipped to any great extent, but the industry is limited to small plantings by market gardeners.

In order to take advantage of the early market, Bermuda onions are harvested as early as possible, generally before the tops have ripened.

These onions are not kept for any considerable period, therefore, it is not essential that they be ripe when harvested.

Northern-grown bulb onions of the common type are usually allowed to ripen before being harvested. This is especially important if they are to be stored, for an immature onion is easily injured and will not keep well. The tops should ripen down and the outer skin of the bulbs should be dry before they are pulled. Most of the bulbs grown commercially are pulled by hand and placed in windrows, consisting of six to eight rows of onions. They are placed in such a way that the tops partly cover the bulbs and protect them from the sun. They are left in the windrows long enough for the tops to wither completely. The length of time required depends on the weather and may be 3 days, or 10 days to 2 weeks. If rain occurs during this curing, the onions should be turned with a scoop fork or a wooden rake so that they will dry thoroughly.

After the onions are dry the tops are usually removed and the bulbs placed in crates for further curing. The tops are cut off by hand, with ordinary sheep shears, care being taken not to cut too close. One-half to one inch of the tops should be left on the bulb. In some sections onion-topping machines are used; in this case the onions are put up in crates, hauled to a central location, and run through the topper. This machine removes the tops, grades the bulbs into two or more sizes, and delivers them into the crates or bags.

Curing.—Onion bulbs that are to be sold during the winter are usually thoroughly cured before being placed in storage. When crates are used for the curing, the bulbs are placed in them as soon as the tops are removed. The filled crates are usually stacked in the field, where they are covered with boards, roofing paper, or other covering to protect the onions from injury by sun and rain. Sacks are sometimes used instead of crates. They are filled and set upright on poles or boards to keep them off the ground. A third method of curing is sometimes practiced, namely, curing in slatted cribs similar to corncribs. In fact, corncribs are often used. This method requires extra handling which adds to the expense and also injures the bulbs. Sometimes the crates are stacked in open curing sheds instead of being covered in the field.

The length of time required for curing depends largely on the weather conditions and the type of container used. Thorough curing requires 3 or 4 weeks and even longer in some seasons. Very often they are left in the field, or curing shed, until marketed or until freezing weather when they are put into storage houses.

Cleaning and Grading.—After the onions are well cured, they are usually run over a sorting rack where the "thicknecks" and injured or decayed bulbs are picked out, while the dirt and small bulbs fall through the slats. At the same time the dry loose outer scales are rubbed off leaving the bulbs bright and clean. The sorting rack is often made so that the bulbs can be graded into two or more grades, based on size, as they pass down over the rack. The very small onions, those below ¾ inch in diameter, fall through the first section of the rack, those between ¾ inch and 1¼ or 1⅜ inches fall through the second section, and the large bulbs pass on out at the end. If only one market grade is made the slats or rods of the sorting rack are generally 1¼ inches apart, so that all onions above that size pass over and those below fall through and are discarded.

The importance of careful grading is illustrated by data given by Gaylord (1927) on the price received for onions that made the U. S. No. 1 grade and those that did not. During the seasons of 1923 and 1924, the Indiana Onion Growers' Exchange shipped 1,100 cars of onions to 88 different markets. All of these were inspected by government inspectors. Of these, 777 passed and 333 failed to make the grade. Gaylord reports that the 777 cars of U. S. No. 1 onions sold for 50 per cent more per car than those that failed to make the grade. It should be noted that these were not ungraded as they had been run over a screen and were supposed to be U. S. Grade 1.

> Often the cars failed to make the grade because the onions exceeded by a small percentage the tolerance allowed . . . As a result, from 1 to 5 pounds of bad onions per sack often threw the car off grade and resulted in a large loss.

The Bureau of Agricultural Economics, U. S. Department of Agriculture, has worked out grades for northern-grown domestic onions and for Bermuda onions. These grades should be used under most conditions. Copies of the grade specifications can be obtained from the Department, and, in many states, from the state marketing agency.

Packing.—Onion bulbs are placed on the market in crates, hampers, round-stave baskets, and bags. In some regions bushel hampers and bushel baskets are used for shipping early onions. Bags are the most common shipping containers for onions as these are cheaper than any other. Only clean bags should be used.

Bermuda onions grown in Texas are marketed mainly in slatted crates holding about 1 bushel. Most northern-grown onions are put up in open-weave paper-fiber or burlap sacks holding 50 or 100 pounds. Some growers use smaller sacks for local and roadside markets.

No special method of packing is used, but it is important that the containers be well filled to prevent the bulbs from rolling around. If the onions have been in storage for some time they should be regraded before being packed so as to remove any that have begun to decay or are otherwise injured.

Storage.—Onions to keep well should be well ripened and thoroughly cured before being placed in storage. Immature, soft, and thick-necked bulbs should be sold as soon as harvested.

The essentials for successful storage are thorough ventilation; uniform, comparatively low temperature; dry atmosphere; and protection against actual freezing. Ventilation is provided by openings near the floor and through the roof of the storage house, but to insure circulation of air through the onions it is necessary to provide air spaces between the containers. Where crates are used, the tiers are separated by 1-inch strips and a space of 1 inch or more is left between rows.

Wright, Lauritzen, and Whiteman (1935) recommend a temperature of 32°F. and a relative humidity of about 64 per cent. They state that sprouting in stored onions was influenced little by the humidity, but was increased with increased temperature. Rooting increased with increase in humidity and was little influenced by temperature. Decay showed only a slight tendency to increase as both temperature and humidity increased. The temperatures maintained in the studies were 32°, 40°, and 50°F., and the humidities were high, medium, and low with the per cent varying with the temperature.

To maintain a low degree of humidity, the storage house should be built entirely above ground and the ventilators and other openings should be kept closed during cloudy or rainy days. In some instances, a drying agent, usually calcium chloride, is used to absorb the moisture from the atmosphere. This material is often used in cold-storage houses and is very important when the temperature is allowed to go above the freezing point and cause melting of ice from the refrigerator pipes.

Cold storage is being employed to a considerable extent for onions and is increasing in importance each year. In cold-storage warehouses it is possible to maintain a low temperature throughout the storage period, thereby keeping the bulbs in a dormant condition. The temperature should be kept at or below the freezing point to prevent drip from the pipes. There is no danger of freezing the onions unless the air temperature goes below 28°F. and remains there for a considerable period.

Cost of Storage.—A study of the cost of storage was made in Massachusetts in 1914–1915 by Cance, Machmer, and Read (1916), covering 22 houses with a total capacity of 486,900 bushels of onions. The overhead cost at that time was 5.3 cents per bushel distributed as shown at the top of page 345.

The present cost probably is greater than this since all items entering into building construction and repair are much higher than in 1914–1915, and taxes have increased greatly. In addition to overhead charges, other items such as shrinkage, cost of hauling, regrading, and handling, should be added. According to Cance, Machmer, and Read, to regrade and sack 250 bags of onions it took five men 1 day; to load and unload, one man 2 hours; to haul to the station, man and team 1 day. Shrinkage probably averages from 10 to 15 per cent. Gaylord (1927) reported results of a study made to determine the loss in 35 storage houses in Indiana in 1925–1926. Over 6,000,000 pounds of onions were involved and the loss averaged 11.35 per cent exclusive of actual loss in weight. This decrease in weight averages at least 5 per cent for a normal storage period and consists of loss of water, sugars, and other products used in respiration. The cost of storage should be charged against the marketable onions taken from storage.

Interest on investment including buildings, crates, bins, etc. $211,000 at 5 per cent	$10,550.00
Taxes	2,331.55
Insurance on buildings and equipment	2,500.00
Insurance on onions 486,900 bushels at 30 cts., $6 per $1,000	876.42
Depreciation at 3½ per cent	7,385.00
Repairs 1 per cent	2,110.00
Total overhead charges	$25,752.97
Overhead charges per bushel	$0.053

Growing Onion Sets.—Onion sets are the small bulbs produced from seed sown very thickly. A large part of the set crop of the United States is produced in the vicinity of Chicago, although a few are grown near Louisville, Ky.; Chillicothe, Ohio; and at a few other points.

The best soils for them are loose sandy loams and silt loams. While rich soils are not especially desired, the areas devoted to onion sets contain soils much above the average trucking soil in quality. The size of sets on these soils is controlled largely by very thick seeding. Even with a heavy rate of planting some of the bulbs grown are too large for sets and are usually sold as "picklers." Bulbs over 1 inch in diameter should not be used as sets.

The quantity of seed used for growing sets is determined by the richness of the soil. On poor soils 40 to 60 pounds are used, on medium rich soils 60 to 80 pounds, and on rich soils 80 to 100 pounds of seed are planted to the acre.

The seed is sown by hand seed drills or by gang drills of the types used for planting seed for large onions. Some growers use special seeders which distribute the seed in several rows about an inch apart; others place a funnel-shaped spreader on the spout, which distributes the seed over an area 3 or 4 inches in width. The distance between rows is usually 12 to 14 inches although closer planting is sometimes practiced.

The general methods of culture are the same for onion sets as for large bulbs.

In harvesting, the sets are first loosened by means of an onion harvester, an attachment for the wheel hoe, which runs under the row. They are gathered in bushel baskets and dumped into shallow, slatted trays to dry. Topping is seldom necessary since the small tops shrivel. The trays of sets are left spread for a day or two, then they are piled one above the other in the field with a space of 3 or 4 inches between. A temporary roof is placed over the pile of trays. The sets are left in the field until they are dry, then they are screened and removed to the storage house. The sets are stored under conditions similar to those used for large bulbs.

LEEK

The leek (*Allium porrum* Linn.) is a biennial grown for its blanched stems and leaves. It is believed to be a native of the Mediterranean region, where it has been in cultivation since prehistoric times. It was known by the ancient Greeks and Romans. It is not grown in this country to any great extent, but is produced on a small scale by market gardeners near large cities, and is consumed largely by the foreign population.

Leeks are propagated entirely from seed, which may be sown in a greenhouse or hotbed, the young plants being transplanted in the garden at the proper time, or they may be sown in rows where the crop is to mature. The method of planting and the distance are about the same as for the onion. In fact the general culture of the crop is very similar to that given the onion, except that leek plants are blanched by banking with soil. The soil is worked up to the plants gradually as they grow, care being taken not to bank up too early as the plants decay easily when young.

The varieties of leeks catalogued by American seedsmen include London Flag, Scotch Flag, Giant Carentan, and Large Musselburgh. These varieties are not very distinct and it is probable that the last two are the same.

Leeks are marketed in bunches like green onions. They are eaten raw alone or in mixed salads, and cooked as flavoring in soups and stews.

GARLIC

Garlic (*Allium sativum* Linn.) is a hardy perennial plant native of southern Europe. It was known to the ancients and is said to have been disliked by the Romans on account of the strong odor, but was fed to their laborers and soldiers. It was used in England as early as the first half of the sixteenth century.

Garlic differs from the onion in that, instead of producing one large bulb, it produces a group of small bulbs called cloves. This group is covered with a thin skin. The seedstalk is similar to that of the onion and bears both seeds and bulblets in the same head. The seed, however, is seldom used for propagation as the cloves and bulblets give better satisfaction. Cloves are more commonly used.

Garlic is grown commercially in California, Louisiana, Texas, and Arkansas. It thrives best on fertile, well-drained loamy soils, but any soil on which onions grow well would be satisfactory for garlic. The methods of planting garlic are similar to those used for onion sets. In the South and in California, planting is done mainly in the fall. The cultivation, fertilization, and general care should be about the same as for onions.

Harvesting usually begins as soon as the tops are dead. In California, according to McCallum (1934), the garlic crop is harvested in June and July. The plants are loosened by running a cutting bar under the bulbs; they are then pulled by hand and placed in small bunches in windrows where they are left until the tops become dry. In California the plants are moved from the windrows to a central point in the field and are stacked in piles for about a week to cure. The tops are then cut off with sheep shears, leaving about an inch. The roots are also cut off about ½ inch below the bulb. The bulbs are allowed to cure for 10 to 14 days in piles in the field; they are then graded and placed in 50- or 100-pound open-mesh bags for market, or for storage.

Another method of handling the garlic after the plants are harvested is to plait the tops together in such a way as to hold the bulbs on the outside. The plaits are hung in a dry, airy place to cure, after which several braids are fastened together into a large bunch which may be 4 feet or more in length.

Garlic is used largely as flavoring in soups, stews, and to some extent in pickles. It is not popular with Americans but is grown largely for foreigners, especially those from southern Europe. A considerable quantity is imported since the production in this country does not supply the demand.

SHALLOT

The shallot (*Allium ascalonicum* Linn.) is believed to have come from western Asia. It is a perennial, seldom produces seeds, but the bulb when planted divides into a number of cloves, which remain attached at the bottom. It has been in cultivation from a remote period. It is mentioned and figured in nearly all old works on botany.

The crop is grown commercially in the southern part of Louisiana to the extent of about 1000 cars according to Jenkins and Miller (1931). The first planting of sets is made there late in August or in September for the early fall crop and for producing plants for setting later crops. For later commercial plantings strong, healthy clumps of plants or clones are used. These clumps are divided and set out 6 to 8 inches apart in rows 3½ to 6 feet apart. The same general care is given as for the onion except that the shallot is blanched by banking with soil. At first, about 2 inches of soil is worked against the plants and 2 or 3 weeks later 2 inches more is added. Banking with soil begins at least 5 weeks before time for market.

Shallot plants are harvested and prepared for market in about the same way as are green onions. They are cleaned, bunched, tied, and packed in paper-lined crates or baskets with crushed ice. When the shallot is grown for the dry bulb, the method of harvesting and handling is similar to that used with onion bulbs. The flavor of shallots is more delicate than that of onions.

CIBOL (CIBOULE) OR WELSH ONION

Cibol (*Allium fistulosum* Linn.) is a perennial but is grown as an annual or biennial. It is a native of Siberia or the East, and was introduced into England about 1629. It does not form a real bulb but only a small enlargement at the base. It is grown for its leaves which are used in salads.

This plant may be propagated by division or by seeds, the latter being preferred. The seeds are sown where the plants are to grow, giving about the same space as for green bunching onions. The culture given green onions is satisfactory for this crop.

CHIVE

Chive or cive (*Allium schoenoprasum* Linn.) is a perennial, probably a native of Europe. It is not grown to any great extent in America, although it is listed in seed catalogues. The plant grows in thick tufts and produces very small, oval bulbs forming a compact mass. It is always propagated by division of the tufts, since seed is rarely produced. While the plant is perennial it is a good plan to take up the clumps and replant them every 2 or 3 years.

Chives are used as seasoning and are much grown in European gardens. They are very popular with the Scotch and are considered almost indispensable in omelettes. The plant is grown for its leaves which are cut off with a knife. The cutting seems to stimulate fresh growth.

CHAPTER XXII

THE POTATO[1]

The average annual world production of the potato is now about 6,000,000,000 bushels having a value nearly, if not quite, equal to that of wheat, which has for years been recognized as the world's leading food crop. The five principal world food crops are corn, wheat, rice, oats, and potatoes. Potatoes rank first in total bushels produced and rival wheat in total value. There is probably no food article in the daily diet of the white race more common than the potato. It contains nearly 80 per cent water in its uncooked state. Most of the remainder consists of about 2 per cent protein and 18 per cent starch. The potato is one of the cheapest and most common sources of carbohydrate food.

Statistics of Production.—Of the total world production, Russia produces about 1½ billion, Germany about 1½ billion, Poland about 1 billion, France about 500 million, and the United States about 400 million bushels. More than three-fourths of the world's crop, therefore, is produced in the five countries mentioned.

According to the census for 1929, the rank in value of the principal groups of crops grown in the United States was cereals, cotton, hay and forage, vegetables, and tobacco in the order named. The total value of all vegetables was approximately 750 million dollars and the potato crop had a value nearly equal to all other vegetables combined. About 47 per cent of all farms grew potatoes. These farms reported, in 1929, an average of 0.8 acre per farm, a yield of 109.5 bushels per acre, and an average value of $64 per acre. The acreage, production, value, yield per acre, and percentage of total United States acreage for the leading potato states and for the United States as reported by the census of 1935 are shown in Table XXXIX.

These figures indicate that over 49 per cent of the total acreage and about 59 per cent of the total crop were produced in seven states. The fact that these states border on Canada or the Great Lakes indicates the importance of cool climate for this crop.

The per capita annual consumption of potatoes in the United States varies between 2.5 and 3 bushels while in western European countries, where production is more intensive, consumption is considerably greater.

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[1] The material on potatoes was prepared by E. V. Hardenburg, Professor of Vegetable Crops, Cornell University.

Our foreign trade in potatoes is relatively small. Whereas our average annual exportation for 1932 to 1936 inclusive was 1,203,000 bushels, our average annual importation for the same period was 1,064,000 bushels. This leaves an average annual net exportation of only 139,000 bushels.

History and Taxonomy.—The potato is undoubtedly a native of South America where it was in cultivation by the natives long before the discovery of America. In fact it is believed by some authorities that it was cultivated at the time of the Incas (Sturtevant). It probably was carried to Spain from Peru early in the sixteenth century. There is some controversy as to whether the potato was introduced into this country from Europe, or brought direct from South America by Spanish explorers. At any rate, it was known in continental Europe and to the colonists of Virginia almost simultaneously and as early as the latter part of the sixteenth century. It remained for the early English colonists of Virginia to introduce the potato as a food plant into England about 1586. As a food it did not become generally popular in Europe until the middle of the eighteenth century, some time after being freely eaten by the whites and Indians in the North American colonies. During the next hundred years, however, production developed rapidly throughout temperate Europe and America. The seriousness of the famous Irish famine of 1846, due to loss by blight rot of the potato crop of Ireland in that year, is evidence of the extreme dependence of the masses of western Europe upon this food.

TABLE XXXIX.—ACREAGE, PRODUCTION, VALUE, YIELD PER ACRE, AND PER CENT OF TOTAL U. S. ACREAGE OF LEADING STATES, ACCORDING TO CENSUS OF 1935

State	Acres	Production, bu. (000 omitted)	Value (000 omitted)	Yield per acre, bu.	Per cent of total U. S. potato acreage
Maine	169,243	54,756	$ 11,256	323.5	4.7
New York	268,397	38,400	11,067	143.1	7.5
Michigan	322,605	36,163	9,605	112.1	9.0
Pennsylvania	225,691	32,745	13,940	145.1	6.3
Wisconsin	295,930	31,783	9,083	107.4	8.3
Idaho	123,724	23,801	6,926	192.4	3.5
Minnesota	359,045	20,538	7,949	57.2	10.0
United States	3,582,344	403,420	160,099	112.6	100.0

The members of the family Solanaceae, of which the potato is the most important, all contain the chemical solanine. Some of the better-known relatives of the potato are tomato, tobacco, pepper, eggplant, henbane, belladonna, petunia, Jimson weed, black nightshade, and bittersweet.

Of the several hundred species of Solanum, very few have the habit of forming tubers on their underground stems. Of these few tuber-bearing species, only four produce tubers of sufficient size to command commercial attention. These in the order of their importance are *S. tuberosum,* the common white cultivated potato of commerce; *S. commersonii,* a colored form used to a limited extent by the peasantry of western Europe; *S. jamesii,* the wild potato of Arizona used by the Indians of that region; and *S. maglia* the wild potato common to the Rocky Mountains.

The plant attains an average height of 2 to 3 feet depending upon variety and environment. The stems are angular, solid, and often winged in cross section and bear compound leaves with leaflets opposite and decreasing in size from apex to base of the leaf. The blossoms are borne in clusters, each consisting of a rotate five-pointed corolla subtended by a similar shaped calyx. The corolla color varies with the variety from pure white to deep purple or violet. The true fruit or seed ball of the potato is nearly spherical, ½ to 1 inch in diameter, and in its pulp are from 100 to 300 pear-shaped seeds. Few seed balls are developed on our present standard varieties, due apparently to such causes as paucity of viable pollen, premature dehiscence of flower buds, and degeneration of flower parts. Apparently neither flowering habit nor seed-ball formation is, however, correlated with tuber yield. The potato tuber represents an enlarged, foreshortened portion of the underground stem. The tuber is usually borne at the terminus of the stolon although occasionally lateral sessile tubers occur. According to the investigations of Clark (1921), tuber formation begins at about the end of the period of flower-bud development and practically the entire crop of tubers is set at this time. Obviously, therefore, the favorableness of soil conditions and of climate during this period in the life of the plant is of much importance.

Denny (1929) studied the role of the mother seed potato in a series of experiments in which the seed piece was amputated at various stages in the growth of the plant. The stages at which the seed piece was removed were (1) sprouts just emerging from the soil, 22 days after planting, (2) plants 2 inches high, 29 days after planting, and (3) plants 10 inches high, 42 days after planting. Using Cobbler and Triumph varieties, he found that yields were significantly reduced by removing the mother tuber at both the first and second stages of growth. Seed piece removal at the third stage of growth when the plant had a well-developed root and stolon system did not significantly affect subsequent yields.

Climatic Requirements.—Climate is decidedly a limiting factor in potato production. In its response to seasonal temperature and rainfall, the potato ranks with corn and cotton. The high average annual yields obtained in Maine, in Scotland, Ireland, England, and northern Germany are due in large part to the cool growing season of these regions. According to the U. S. Department of Agriculture (1920) of a total average annual loss from 1909 to 1919 of 30 per cent in the potato crop of this country, over 20 per cent was due to adverse weather. Growing-season temperatures ranging from 60° to 75° F. are most favorable. Maine is the only state in this country situated north of the 65° isotherm. J. Warren Smith (1915) correlated monthly and total growing-season temperature and rainfall with the average annual yields of potatoes in Ohio over a period of 55 years. He found a very significant negative relationship between temperature and yield and an almost equally significant positive relationship between rainfall and yield in that state. He also found by the correlation method that July weather in Ohio is more influential on potatoes than the weather of any other month, doubtless due to the fact that this being the time when the plant is blossoming and setting tubers, is a critical period in the life of the plant. Fox (1916) similarly correlated these climatic factors with yield in New York for a period of 26 years and obtained results agreeing with those of Smith except that the rainfall and yield correlation was negative instead of positive. This indicates that, whereas rainfall is usually a limiting factor in Ohio, the years of highest rainfall in New York have been years of severe loss in the potato crop from rot due to the late blight fungus, *Phytophthora infestans*. The states having highest average yields in this country are not those leading in total production but rather those intermountain states of the West where the crop is grown on the higher plateaus under irrigation. These limited areas are provided with ideal temperature and moisture conditions through elevation and a controlled water supply. Some of the southern states produce a part of their own seed stock by growing it at the higher mountain elevations in order to take advantage of cool growing-season temperatures. Mulching of seed plots is also sometimes practiced, the influence of the straw or other mulch material being to maintain a lower average soil temperature than would otherwise be available. One reason why early or short-season varieties predominate in the southern states is the necessity of growing and maturing the crop early enough to avoid the high temperatures of midsummer.

In recent years, much research has been done on the effects of temperature and soil moisture on growth and yield. Bushnell (1925), in a greenhouse series of thermoregulated chambers, grew potato plants at temperatures of 20°, 23°, 26°, and 29°C. Since 17°C. is known to be about optimum for tuber yield, these experiments provide information on the effects of high temperatures. As temperatures increased, the size of both leaves and tubers decreased. At 29°C. no tubers formed. Bushnell's data are especially noteworthy in showing that (1) "respiration during the night in the aboveground part of the plant increased with temperature" and (2) "the reduction in the carbohydrate available for translocation which resulted from the increased respiration at the higher temperatures, roughly corresponded to the reduction in tuber growth. Thus, the rate of tuber growth appeared to be a function of the available carbohydrate."

In a greenhouse soil culture experiment, Hardenburg (1923) found that air temperature exerted a decided influence on tuber-set in the Number 9 variety. Comparing the results from a 14 weeks' period of growth under average daily temperatures of 59° and 69°F., the tuber-set per plant was 24.6 and 55.8, respectively, while the average weight per tuber was considerably smaller under the higher temperature. Stolon number and stolon weight were consistently greater under the higher temperature, also.

Soil Preferences.—Of the two factors, climate and soil, the latter is undoubtedly much less important as a factor limiting yield than the former. The influence of soil on potatoes is measured in yield earliness of maturity, eating quality, keeping quality, and the loss from disease. The ideal soil for potatoes is one which is naturally rich, of medium texture, friable, deep, and not highly alkaline. Extra light soils are not sufficiently retentive of moisture to supply the normal water requirements of the plant and are usually relatively poor, especially in humus. Extra heavy soils when wet are more conducive to blight-rot development in the tubers, and when dry are subject to baking and generally result in greater difficulty in digging the crop. The Wooster series and the Washburn series of loam soils on which the famous yields are produced in Aroostook County, Maine, being of medium to light texture, of glacial drift origin, and naturally well supplied with humus, are ideal for this crop. The fairly light soils of northern New York, Long Island, New Jersey, and Virginia all produce bright skinned potatoes of excellent eating quality. These sandier soils are inherently lower in potash than the heavier soils farther inland. In many of the older potato-growing regions along the Atlantic seaboard, evidence of so-called potash hunger has been shown where little potash has been applied in recent years.

The use of muck and peat soils for potato growing is annually increasing. Large yields are obtained in the delta region of the San Joaquin and Sacramento River valleys of California on soil which is known as tule land. Considerable peat-soil acreage is devoted to both seed and table-stock production in Minnesota and Michigan. A somewhat smaller acreage is also produced in New York. There is some prejudice against the quality of muck-grown potatoes, but this is probably not justified as potatoes of excellent quality are being grown on well-drained and properly fertilized soils of this type. Large applications of potash are usually necessary on these organic soils, especially during the first few years after being reclaimed. Not all varieties of potatoes are well adapted to muck soil, but Irish Cobbler, Triumph, Warba, Katahdin, and Chippewa seem to be well adapted to it.

Hardenburg (1926) has shown that soil type influences the shape of the tuber in that the lighter, better aerated soils produce tubers which more nearly approach the ideal or standard types than do the heavier soils. Clark (1921) from a single year's test of the influence of soil type on the number and yield of tubers per hill in two varieties, found that as the soil type became lighter the number and yield of tubers per hill increased. Hardenburg (1923) studied the influence of soil moisture on yield and tuber-set in greenhouse experiments maintained at constant temperatures approximating 59° and 69°F. Soil moisture was kept at 17, 20, and 23 per cent of saturation under each temperature. He concluded: "Although both the weight of tubers per hill and the average tuber weight were increased as the soil moisture increased, a corresponding influence on number of tubers set did not occur." In the low-temperature series, the set increased as the moisture decreased, while the reverse occurred in the high-temperature series.

Rotations.—Except in a few important potato-producing regions such as Long Island, N. Y., the eastern shore of Virginia, and in the trucking regions of the South, the crop is rotated in cropping systems varying in length from 3 to 5 or more years. Ideal soil and market conditions and the relatively high land values on Long Island make the continuous production of potatoes desirable in this region. In recent years, growers have depended upon winter-grown, green-manure cover crops of rye to maintain the soil humus supply necessary under these conditions. Generally, however, potatoes follow a sod crop in the rotation. The most common rotation in Maine is potatoes, oats, clover, while in New York it is potatoes, oats, hay 2 to 3 years. The relatively high nutrient requirement of the potato makes rotation desirable. This tends to prevent soil depletion and the accumulation of potato disease organisms that live in the soil. Macoun (1905) has shown that clover is a very desirable legume crop to precede potatoes. It adds humus in a desirable form and has a beneficial influence on soil texture. In the more common 4- to 6-year rotations of potatoes, grain, and hay 2 to 4 years, the sod residue from the older seedings preceding potatoes is often so light as to be of small benefit. In New York, Hardenburg (1923) found a decrease in yield with the increase in length of rotation. These low yields were attributed to the poor quality and low yield of humus in the older seedings. Such soil-infesting potato insects as wireworms and grubs are also more numerous and serious when potatoes follow such old seedings. In regions farther west, where potatoes are rotated with such crops as corn, beets, oats, and alfalfa the longer rotations have given the highest yields (Holden 1920).

Soil Preparation.—Thoroughness in seedbed preparation is obviously important from the fact that soil structure, moisture, temperature, aeration, and available mineral nutrients are all more or less dependent on it and the shape, quality, and yield of the tubers in turn dependent on these factors. Heavy soils are often improved in structure and texture for potatoes by growing such crops as rye and buckwheat. The taproot of the latter tends to loosen the lower, less pervious strata and leaves the entire soil surface in a more friable condition. Rye produces a large amount of organic material in a relatively short time and has the advantage of being hardy and well adapted to acid and poor soils. In its decomposition to form humus, the humic acid formed tends to reduce the alkalinity in soils containing the potato scab organism and thus reduces the loss from this disease. When the crop is to be grown in long rotation with old seedings in which potato insects are often more numerous, corn may profitably precede potatoes, the former instead of the latter following sod. In plowing under coarse corn stubble just before planting potatoes, there is often danger that the undecomposed layer will interfere with the upward movement of water and thus limit the crop. Fall plowing of the heavier soils and of soils carrying coarse organic material is recommended. Very little fall plowing is commonly done, however, because of unfavorable weather and competition with other farm work. Shallow soils with hardpan layers close to the surface can be improved for potatoes by a gradual increase in depth of plowing each year to enlarge the soil area suitable for tuber development. Fitting of plowed land for a tilled crop of this kind can scarcely be overdone. Weeds are more efficiently controlled by thorough harrowing prior to planting than by the much more costly and less efficient inter-row tillage during the growing season. Thus it often happens that better final results are obtained by delaying planting until such time as the seedbed is in optimum condition than by early planting and its subsequent difficulties in weed control because of a poor seedbed.

Manures and Fertilizers.—The heavy nutrient requirements of the crop and the relatively large gross income per acre from it are factors that make the use of heavy applications of manure and fertilizer usually profitable. On the sandier soils in the older potato regions of the eastern states, amounts of fertilizer ranging from 1,000 to 3,000 pounds per acre are commonly applied. On the heavier soils farther inland and particularly in such important potato states as Michigan, Wisconsin, and Minnesota, lighter applications, 800 pounds or less, are used.

A relatively higher grade of commercial fertilizer is used on potatoes than on other field crops. Judging by analyses of comparative yields of potatoes and corn, the potato requires about one-half as much nitrogen and twice as much phosphorus and potassium as the latter. Nearly all complete potato fertilizers analyze high in the last two elements. Before the World War, 2–8–10 was the analysis commonly used. Recently, such analyses as 4–12–4, 5–10–5, 5–8–7, and 10–16–14 have become common. There are very few soils naturally stocked with sufficient readily available potash to give good yields. Both sulphate and chloride or muriate forms of potash are used and experiments indicate no appreciable difference between them in their influence on yields. Muriate of potash is more commonly used because it is cheaper and more plentiful in the market. Comparative tests of influence on quality have in a few cases shown that the chlorine in muriate of potash has reduced the quality of potatoes. There is, however, insufficient evidence on this point. Woods (1918) reported the results of a 4-year test in Maine to determine the effect of varying amounts of potash on yield. Fifteen hundred pounds per acre of a complete fertilizer containing the same amounts of ammonia and phosphoric acid and mixed with no potash, with 300 pounds of salt and with 3, 5, and 7 per cent of potash respectively, was used. Part of the results are given in Table XL.

TABLE XL.—POTASH EXPERIMENT WITH POTATOES, SHOWING YIELD IN HUNDREDWEIGHT PER ACRE, 1915–1918
(Maine Agricultural Experiment Station)

Amount of potash	1915	1916	1917		1918	
		Series 1	Series 1	Series 2	Series 2	Average
None	182	172	131	140	123	150
None + salt	...	193	136	144	130	151
3 per cent K_2O	191	254	135	150	128	172
5 per cent K_2O	191	254	131	157	137	174
7 per cent K_2O	198	244	139	160	134	175

Under these conditions, salt did not appear to liberate potash already in the soil nor did it pay to use over 3 per cent of potash. Phosphatic fertilizers used alone quite generally give more profitable results than any other single element.

Time and method of applying fertilizers are of considerable importance. When planters are used, the fertilizer is commonly applied through a fertilizer attachment just ahead of the seed hopper on the machine. This leaves the fertilizer at each side of the seed piece with a slight covering of moist earth between to prevent contact and burning of the latter. When planters are not used, grain drills, or fertilizer distributers, are common. It is not advisable to drop fertilizer in the hill with the seed piece. Results of a 3-year experiment at the Maine Station indicate that when as much as 1,500 pounds of fertilizer of ordinary concentration is used, it is fully as efficient to apply it all at once and through the planter as to apply it in two applications, or broadcast. Similar results were obtained by Slate and Brown (1920) at the Storrs Connecticut Station in a 4-year test. The New York Station comparing drilling and broadcasting in a 4-year test on Long Island obtained a difference of 7.3 bushels per acre in favor of drilling. Apparently the drill method is to be recommended when the additional factor of cheaper cost of application with the planter is considered.

Stable manure, well decomposed, has long been recognized as a very desirable form of organic fertilizer for potatoes. When the crop is grown on a small scale, it is still commonly used as a top dressing to the sod just prior to plowing. In regions of more extensive production, however, the supply is no longer adequate for the entire acreage. The most efficient place for stable manure in the average rotation is probably as a top dressing to the hay crop the year previous to breaking up sod for potatoes. Thus applied, it increases the quality and yield of hay, becomes well incorporated with the soil, is in a more available form for potatoes, and is less likely to increase scab on the tubers. Farm manures, high in ammonia, because of their tendency to promote activity of the scab organism, should not be applied directly to the potato crop.

Seed.—The majority of growers in the leading potato-growing states produce their own seed potatoes, only renewing from outside sources in occasional years. In contrast, growers on Long Island, in New Jersey, Virginia, and the southern and south central states quite universally procure seed annually from sources farther north. South central and Gulf coast states secure seed potatoes mainly from Minnesota, Nebraska, Wisconsin, Montana, the Dakotas, and the Red River Valley region of Canada, while the seed used on Long Island, in New Jersey, Virginia, and the South Atlantic states is grown mostly in the maritime provinces of Canada, and in Maine, Vermont, and New York. This practice of using northern-grown seed is necessary because the crop as grown under the high, growing-season temperatures of the South is so devitalized as to render it unfit for seed. What is known as second-crop seed is grown to some extent in southern states by planting, late in the summer, northern-grown stock which has been held in cool or cold storage. Planted in late summer, such a crop develops under cooler temperatures and thus retains sufficient vitality to make it of value for seed the next year. Second-crop seed is usually immature when dug and is, therefore, low in yield and relatively expensive.

Southern growers sometimes have difficulty in getting rapid germination of second-crop seed used to plant the main crop. This is due to the rest period of 6 to 8 weeks required between harvest and the time when the tubers are ready to resume growth. Denny (1926) has found that this rest period can be successfully broken by treatment of the tubers with certain chemicals. He found ethylene chlorhydrin most effective of many chemicals tried. For Irish Cobbler, the best treatment seemed to be to cut the seed and soak one hour in a solution of 6 cubic centimeters of the chemical to 1 liter of water. For Green Mountain variety he got best results by dipping the cut tubers in a solution of 30 cubic centimeters per liter of water, afterwards storing the tubers 24 hours before planting. Loomis (1927) found that storage of dormant seed at temperatures of 20° to 30°C. for a period of 4 weeks immediately after harvest was just as effective as ethylene in breaking the rest period. In fact, many southern growers apply this principle by storing in the barn loft at very high temperatures during May and June, tubers from the main crop to be used for planting the second crop.

TABLE XLI.—RESULTS FROM PLANTING MATURE AND IMMATURE SEED POTATOES AT THE ONTARIO STATION (AVERAGE OF 4 YEARS)

Seed potatoes obtained from the crops produced from the plantings of the following dates of the previous year	Average percentage maturity in resulting crop on September 11th	Average yield of 6 varieties (24 tests) in bu. per acre
May 31	57	192.37
June 14	56	194.80
June 28	55	201.84
July 12	53	219.46

The quality of seed potatoes depends upon such factors as disease, storage conditions, and soil and climatic conditions prevailing during growth. Strains of seed degenerate or "run out" from such causes as the incursion of virus diseases and growth and storage under unfavorable temperatures. Immaturity in seed is desirable in so far as it results in less sprout development during storage and a consequent greater vigor and less shrinkage in the seed at planting time. Planting seed stock so late as to prevent its maturity before killing frosts in the fall results in a more desirable type of immature seed than would result by harvesting seed stock planted at the usual time, in an immature condition during midsummer.

The influence of immaturity of seed on the resulting crop is shown in the results of 4 years' work by Zavitz (1916) at the Ontario Station as given in Table XLI.

Although the increased yield due to immaturity is relatively small, the increase is consistent. It is interesting to note that the crop from immature seed was somewhat later in maturing than that from seed which was mature.

Storage of seed potatoes is an important factor too often neglected. Most seed potatoes are stored in house cellars of dirt-floor and stonewall construction. The average temperature is often high enough to promote early development of sprouts and as a result the seed is badly shrunken and low in vitality by planting time. Seed should be stored, if possible, at uniform temperatures ranging from 36° to 40°F.

Bushnell (1927) has shown that refrigerated storage in which the temperature range is 32° to 33°F. may not be so efficient for seed potatoes as good cellar storage in which the temperature range is 36° to 38°F. His data substantiating this conclusion are given in Table XLII.

TABLE XLII.—EFFECT OF STORAGE TEMPERATURE ON POTATO YIELD

Seed stored	Yield in bu. per acre for different dates of planting				
	April 20, 1926	May 11, 1925	May 6, 1924	June 18, 1923	Average
Cellar storage, 36°–38° F......	222	221	242	239	231
Cold storage, 32°–33° F.......	202	198	212	187	200

Bushnell states that 41°F. may be considered the sprouting temperature for seed potatoes, meaning that after the rest period is complete, sprouting will begin at once if the prevailing temperature is above 40°F. In the above experiment, it is evident that the cold-storage seed was too dormant at planting time to allow of prompt germination of the seed pieces after planting. Tubers will not usually suffer damage from freezing at temperatures down to 28°F. Low temperature tends to reduce respiration and, thereby, reduces the rate of loss of soluble carbohydrates and shrinkage. A humidity of about 90 per cent is recommended. Dry air increases the evaporation rate while excessive humidity promotes the development of storage rots. Uniformity of both temperature and humidity is best controlled by proper insulation and ventilation of the storage.

Sun sprouting or "greening" of seed potatoes, a practice more common in Europe than in America, is annually becoming more common as its benefits are better appreciated. It involves exposure of the seed tubers on the ground or floor to moderate or subdued light for a period of about 2 weeks prior to planting. During this time, short, green, vigorous, disease-resistant sprouts are developed and it becomes possible to discard those tubers that develop weak sprouts or no sprouts at all. Sprouts over ½ inch long should not be allowed to develop because of the likelihood of their being broken off in going through the planter. Among the several advantages resulting from the practice of greening are increased earliness of emergence, earlier maturity, and an increase in yield of marketable tubers. Yield, wholly aside from its increase due to greater vigor of the sprouts, is potentially higher because of the greater number of nodes and stolons that develop on the sprout of greened seed between the seed piece and the soil surface. Hardenburg (1935), in summarizing the results of a 4-year experiment on green-sprouting of seed of both Rural and Green Mountain varieties, drew the following conclusions: (1) greensprouting effected an earlier comeup and a more rapid early growth rate, (2) fewer stems per plant resulted from the greening process, (3) greening increased the number of stolons per stem, and (4) greening resulted in an increase in the percentage of U. S. No. 1 yield per acre.

Three factors determine whether seed tubers should be cut or planted whole, namely (1) cost of labor for cutting, (2) cost of seed, and (3) relative efficiency of cut and whole seed. Generally, the comparative cost of seed and labor are such that it is more profitable to cut seed than to plant it whole. Relatively little seed weighing more than 2 ounces, or of hen's-egg size, is ever planted. Most of this is cut. All other factors being equal, whole is better than cut seed because it is less likely to rot or become diseased after planting and because it will not lose vitality through bleeding and drying. Whether small or large tubers are the better for seed depends principally on whether the small tubers are from high-yielding healthy stock or only representative of the culls and small tubers from diseased and low-yielding hills. Stewart (1922) reported that uncut tubers between 1 and 2 ounces in weight are at least as good as, and, probably better than, pieces of equal weight cut from large tubers of the same plant. In his tests, however, a high-yielding, healthy strain of seed was used. Most experiments comparing yields from large and small tubers have resulted in both total and marketable yield in favor of large tubers. Much more seed per acre was planted, however, when the large seed was used.

Formerly, it was thought good practice to apply such drying materials as hydrated lime, gypsum, sulphur flour, and sifted wood ashes to the cut surfaces of cut seed potatoes which must of necessity be stored several days prior to planting. This practice prevented the loss of moisture by rapid drying of the cut surface. Artschwager (1927) and others have recently shown that slow rather than rapid drying is conducive to the formation of a permanent layer of woody cells over the cut area. Two processes are essential to the proper healing of cut seed: suberization of the cut surface and the subsequent formation of a wound periderm beneath. Suberization proceeds at a rate depending on temperature. Relatively high temperature, 65° to 70°F., and high humidity, 85 to 95 per cent, are now recommended for the proper curing of cut seed potatoes. Seed properly cured is protected against drying when planted in hot, dry soil and against rotting when planted in cold, wet, or disease-infected soil.

Size of seed piece has been shown by numerous experiments to have a very pronounced influence on yield. Nearly all tests that compared one-eighth, one-quarter, one-half, and whole tuber seed pieces have resulted in increased total yields for each increase in size of seed used. Most of these tests have shown that as the size of the piece increases, the number of stalks per hill increases, the percentage of marketable yield decreases, and the total marketable yield increases up to the one-half tuber size. The planting of large whole tubers, therefore, has not been generally profitable. With plants spaced equidistant in nearly all of these experiments, the number of bushels planted on an acre was increased as the size of seed piece was increased. Therefore, the increase in yield from large pieces is really a measure of the influence of rate of planting. The results obtained by Zavitz (1916) in a 5-year test at the Ontario Station as shown in Table XLIII are typical:

TABLE XLIII.—SIZE OF SEED PIECE OF POTATO RELATED TO YIELD AT THE ONTARIO AGRICULTURAL EXPERIMENT STATION

Size of seed piece planted, oz.	Eyes per seed piece	Amount of seed used per acre, bu.	Average results for 5 years (10 tests)			
			Percentage of crop marketable	Yield per acre, bu.		
				Marketable	Total	Total less seed used
1/16	1	1.3	61.0	36.8	47.5	46.2
⅛	1	2.6	88.6	78.8	89.7	87.1
¼	1	5.2	89.7	98.4	111.1	105.9
½	1	10.3	88.7	109.4	129.0	118.7
1	1	20.6	89.5	129.9	148.4	127.8
2	1	41.2	87.6	149.7	173.9	132.7

Other experiments by Sprague and Evaul (1929) covering the years 1925 and 1926 show essentially the same results as those of Zavitz.

Emerson (1907) in Nebraska made a test of this factor in which the amount of seed per acre was the same for all sizes of seed piece. Planting one-eighth, one-quarter, and one-half tuber seed pieces, 6, 12, and 24 inches apart, respectively, he used 18 bushels of seed per acre in each plot.

This gave the highets total yield per acre from the one-quarter tuber pieces and the lowest total yield from the one-half tubers. Apparently the most efficient way to use a given amount of seed is to cut it into pieces about 1 ounce in size and plant them relatively close rather than to use larger pieces and plant them farther apart.

Many of the older growers pay special attention to number of eyes on the seed piece when cutting seed. This would be important if pieces as small as, or smaller than, 1 ounce were to be used in order to insure at least one good eye to the piece. But since yield is influenced mainly by size of seed piece irrespective of number of eyes as shown in Table XLIII, the question of number of eyes becomes of only minor importance. Ballou (1910) in Ohio found that as the number of eyes on the seed increased, the number of stalks per hill increased and the yield of unmarketable tubers also increased. However, he also obtained an increase in marketable yield with each increase in number of eyes. Whipple (1915) thinned plots of several varieties in Montana to one stalk per hill and reported a very small increase in marketable yield with practically no difference in total yield. The most important factor in cutting seed appears, therefore, to be that of obtaining a sufficiently large piece to insure at least one vigorous stalk so that the piece may not dry out or weaken even under adverse soil conditions between planting time and the complete establishment of the plant. Chunky pieces are most satisfactory as they are not likely to break or dry out, and they feed through the machine planters better than slender ones.

Planting.—Average date of the last killing frost in spring, soil type, and type or variety to be grown are the factors that really determine the best time to plant potatoes. Planting is usually earlier on light soils at low elevations than on heavy soils at high elevations. Since prices are usually higher on the early market than on the late, early planting is more important with early varieties than with late varieties. If possible, potatoes should be so planted as to bring the period of blossoming and tuber-setting during a time when weather conditions are optimum. Hot, dry weather at this critical period in the life of the plant seriously interferes with the setting of tubers and consequently with the ultimate crop. Under average conditions and with most main-crop varieties, tubers are formed about 6 weeks after the planting date. In the leading potato-producing states, the average date of planting varies from May 15 to June 15. Thus July weather is usually very influential on potato yields.

Erwin and Rudenick (1922) at the Iowa Station studied the relation of date of planting to yield over a 6-year period 1910 to 1916 varying the dates by weekly intervals from Apr. 10 to June 12. The average yield from the April plantings was 124.4 bushels as compared with 76.2 bushels for the June plantings. The authors recommended earlier planting to permit the crop to develop under lower seasonal temperatures than would be possible under the later plantings. Bushnell (1926) at the Ohio Station conducted a similar study through the years 1922 to 1925 inclusive in northern Ohio. Here the season is long enough to mature even the late Rural varieties and date of planting may be adjusted to optimum weather conditions. Planting at frequent intervals from early May to late June resulted in best average yields from the plantings made in late May. However, better early-market prices may make it advisable to plant somewhat earlier even at some sacrifice in yield in certain years.

Although a considerable part of the potato acreage of this country is still planted by hand, machines that drop seed pieces automatically are annually becoming more common. The larger acreages in regions of fairly level topography and few stones are now generally machine planted. Of the two distinct types of planters used, one requires two men, the other, one for its operation. The two-men or platform type, which usually costs a little more than the picker type and is more expensive to operate because of the extra man required, is expected to produce a more nearly perfect stand of plants than the latter. Neither type, however, can be used to plant in checkrows. The relative merits of the checkrow and the drill systems of planting are determined by such factors as cost of labor, value of land, and weed control. The last of these is most important. Under conditions of hilly topography and heavy soil, weed control is often facilitated by planting in checks to allow cross cultivation. Under more favorable conditions, weeds can be as efficiently controlled and yields increased by planting in drills. There are more plants and usually more seed used on an acre under drill than under checkrow planting. Because of this increased stand of plants and amount of seed, yields are commonly higher on fields planted in drills. The results of a study made by Hardenburg (1922) on 947 farms in New York are reported in Table XLIV.

The data in Table XLIV indicate that an average of 3 bushels more seed per acre is used under the drill method in New York. The average number of bushels of seed used in most of the leading potato states varies between 12 and 15 bushels per acre. The majority of station experiments indicate that as many as 18 bushels of seed could more profitably be used. In Great Britain and the countries of western Europe as much as 25 to 35 bushels of seed per acre is common. In those countries, potato land is relatively expensive and labor relatively cheap. Under such conditions, hand tillage can be economically used. Stuart (1937) gives figures showing the relation of size of seed piece and spacing of plants to the amount of seed required to plant an acre. His tabulation shows that more than 54 bushels of seed would be required to plant an acre if 2-ounce seed pieces were planted as close as 8 inches apart in rows 30 inches apart. But if ½-ounce seed pieces were planted 36 inches apart, in rows 48 inches apart, only 1.9 bushels of seed would be required. The common distance between rows is 30 inches to 3 feet. In checkrow planting, 3 feet is the usual distance between plants, while in drills the average spacing is between 8 and 16 inches. Early varieties that produce smaller foliage growth may be planted much closer than late varieties. The decrease in yield due to missing hills is not in absolute proportion to the number of such missing hills. Stewart (1921) in New York found that about one-half of the loss in yield due to a missing hill is made up by the two hills adjacent to the vacant space.

Table XLIV.—Relation of Potato Planting System to Yield on 947 Farms in New York

Region	Planted in drills			Planted in checkrows		
	Number of farms	Average yield per acre, bu.	Average amount of seed used per acre, bu.	Number of farms	Average yield per acre, bu.	Average amount of seed used per acre, bu.
Steuben County 1912......	101	153.0	12.2	251	129.2	9.2
Monroe County 1913.......	221	128.5	13.2	77	120.6	10.2
Franklin and Clinton counties 1913..............	54	188.4	14.5	243	177.2	11.4
Total................	376	.....	....	571		
Average...............	...	156.6	13.3	...	142.3	10.3

Depth of planting varies mainly with soil type and with the system of culture. Although 4 inches is about average, the depth is commonly more shallow on heavy soils and deeper on light soils. Irrespective of depth planted, tubers tend to develop at the 4-inch depth. This is due to the fact that conditions of soil moisture and temperature are optimum for growth at this depth. On the heavier soils, the seed is commonly planted quite shallow and a system of gradual to steep ridging is practiced during the growing season. This provides against injury to the crop from excessive rainfall and makes digging easier. Extreme ridging is practiced chiefly in Maine, western New York, in the South, and in the irrigated sections of the West. Elsewhere more nearly level culture is practiced. In regions where the soil is light and rainfall is likely to be insufficient, ridging is sometimes overdone with the result that the soil dries out and growth is retarded at midseason.

Cultivation.—The potato, like all other intertilled crops, responds to good cultivation. But tillage may be, and frequently is, overdone.

More frequently, however, it is either insufficient or at least inefficient. Of the two primary objects of cultivation, moisture conservation by a soil mulch and weed control, the latter is much the more important. Deep cultivation is seldom, if ever, justified since such cultivation destroys the roots in the surface and does not increase the depth of penetration of other roots, as is claimed by some workers. The effect of depth of cultivation on the root system in the surface few inches of soil is shown in Fig. 53 and 54. If the roots are cut off by the cultivator, the potato plant is unable to make use of the moisture and nutrients in the soil to the depth cultivated. The experiments of both Stone (1905) and Emerson (1907) indicated that from six to nine cultivations a season were more effective than either a greater or less number. Fewer cultivations would not control weeds while a greater frequency usually resulted in injury to the plant late in the season. Thompson *et al.* (1931), in a 4-year experiment on Lond Island, compared yields resulting from no cultivation (weeds scraped off) with those from plots cultivated half of the season (four to six times) and plots cultivated all season (seven to nine times). The scraped plots outyielded both of the cultivated plots by a significant difference every year of the four. Cultivation during half the season gave yields as high as cultivation throughout the season,

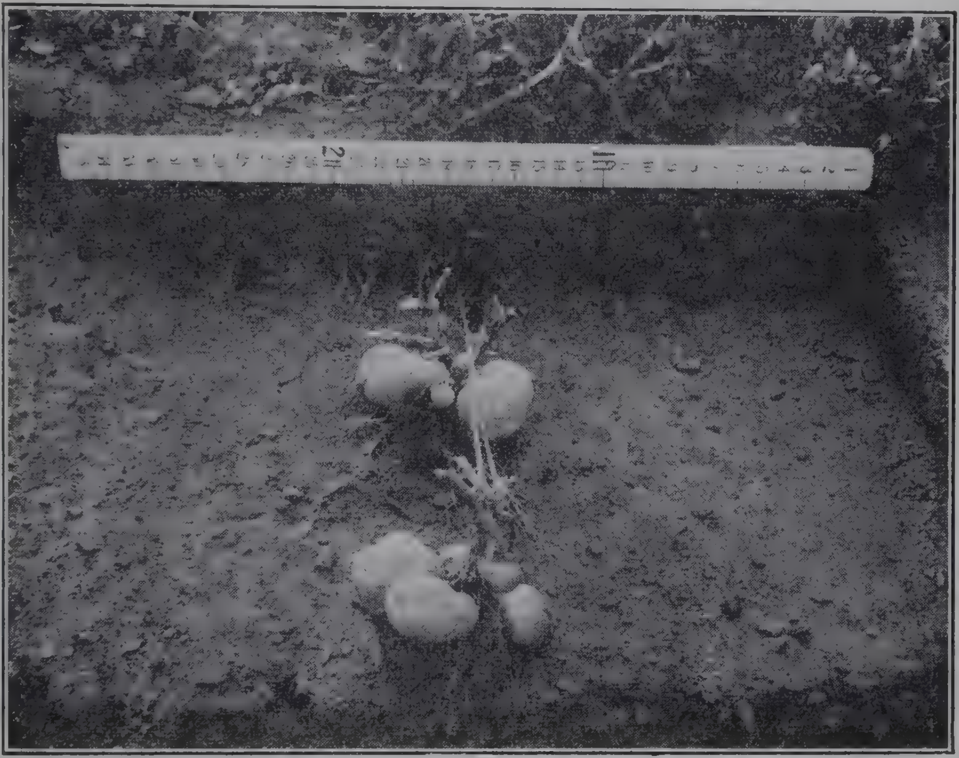

FIG. 53.—Root distribution of potato plants 95 days after planting. Roots pruned to depth of 4 inches and 4 inches from either side of row when plants were about 6 inches high, and repeated once a week for three weeks. (*Courtesy Cornell Univ. Agr. Exp. Sta.*)

the small difference being not significant. Moore (1937) reported on the interrelationship of depth of planting, degree of ridging, and yield. The following is quoted from his conclusions: "Considering all of the data, it seems safe to conclude that the lower soil moisture, the higher soil temperature at the level of the tubers, and the higher soil nitrates are all conditions found in ridged soil that are unfavorable to high yields of potatoes. Of these, moisture is the most important. Root pruning by cultivation may nullify all the environmental conditions otherwise in favor of level culture." Time of cultivation is, after all, more important than frequency. Tillage is of little or no benefit and may be injurious after the tubers have set and the foliage covers the soil surface.

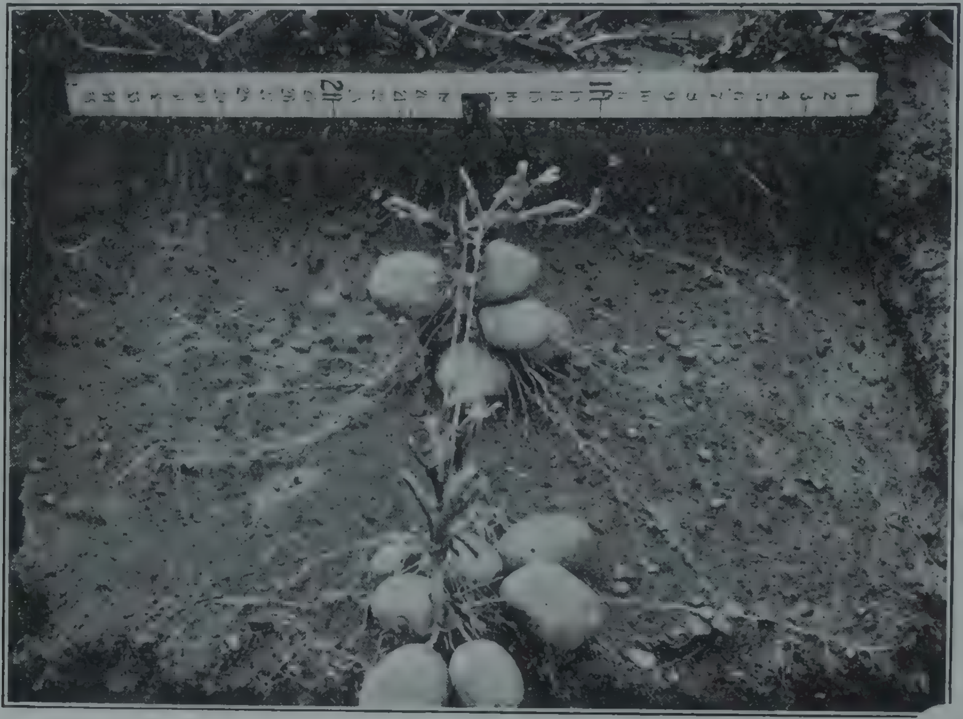

FIG. 54.—Root distribution of potato plants 95 days after planting. Roots not pruned. Compare with Fig. 53. (*Courtesy Cornell Univ. Agr. Exp. Sta.*)

Varieties.—The various and promiscuous methods by which potato varieties have come into existence have resulted in the production of far too many varieties of uncertain origin and commercial value, and in much confusion in nomenclature. Many of our present so-called varieties are the results of selection for change or improvement in type of tuber, or yield. Many are the results of simply renaming old varieties. There are three methods by which varieties have distinct origin; namely, crossing, mutation, and production of seedlings from spontaneous seed balls. Of these three, varieties from seed balls are most common. Such standard varieties as Sir Walter Raleigh, Norcross, Burbank, Rural New Yorker No. 2, Carman No. 3, Early Rose, and Early Ohio originated directly from seedlings. Green Mountain, Chippewa, Warba, Katahdin, Houma, and Sebago are examples of origin by crossing; while Pearl, White Ohio, Pioneer Rural, and Russet Rural are examples of the results of mutation. Varieties Number 9 and Heavyweight are the products of selection for increased yield from older varieties of the Rural type. The fact that most of the varieties which were popular 80 years ago are no longer grown extensively has led to a popular impression that varieties "run out" because of senility. Such varieties as Garnet Chili, Black Chenango, Cowhorn, Blue Mercer, Meshannock, and Early Peachblow are scarcely found today. There seems to be no valid evidence, however, that they have disappeared because of old age. High-yielding strains of each may still be found in cultivation, but the present potato market is against such colored-skinned, ill-shaped, deep-eyed, and poor-quality varieties. The majority of evidence indicates that neither varieties nor strains degenerate with senility, but rather that seed stocks do become more or less worthless as they become badly affected with such virus diseases as leaf roll, spindle tuber, and mosaic. Unfavorable growing season and storage environment are also considered to be contributing factors.

Although hundreds of varieties are being grown throughout the United States, most of the commercially important ones can be associated into 12 groups on the basis of similarity of foliage, tuber characters, and season of maturity of the varieties within each group. Such a group classification and description, made by Stuart (1923), follow:

Group 1. *Cobbler.*

Tubers: roundish to roundish flattened or slightly oblong; stem end usually deeply recessed or notched; skin creamy white.

Sprouts: base, leaf scales, and tips slightly or distinctly tinged with reddish violet or magenta. In some cases the color is nearly, if not entirely, absent.

Flowers: light rose-purple; under intense heat may be almost white. Plants flower very profusely in some sections.

Group 2. *Triumph.*

Tubers: roundish to roundish flattened; skin solid red or magenta in the case of the Triumph to creamy white with more or less numerous splashes of red or carmine in the case of Noroton Beauty; white with faint to pronounced coloring in the eyes in the case of White Triumph; maturing early.

Sprouts: base, leaf scales, and tips more or less deeply suffused with reddish violet.

Flowers: very light rose-purple; rather small; flowers sparingly.

Group 3. *Early Michigan.*

Tubers: oblong or elongate flattened; skin white or creamy white, occasionally suffused with pink around bud-eye cluster in Early Albino.

Sprouts: base light rose-purple; tips creamy white or light rose-purple.

Group 4. *Rose.*

Tubers: elongate flattened to spindle-shaped flattened in section 1, or oblong flattened in the case of section 2; skin flesh-colored or pink; bud-eye cluster deep magenta; in the case of the White Rose the skin is white.

Sprouts: base and internodes creamy white to deep rose-lilac; leaf scales and tips cream to rose-lilac.

Group 5. *Early Ohio.*

Tubers: round oblong, or ovoid, generally slightly flattened though not always; skin flesh-colored or light pink, usually with numerous medium-sized, rather conspicuous russet dots or lenticels.

Sprouts: base, leaf scales, and tips more or less deeply suffused with carmine-lilac to violet-lilac or magenta.

Flowers: white; moderate bloomer.

Group 6. *Hebron.*

Tubers: elongated and distinctly flattened, sometimes spindle-shaped; skin creamy white, more or less colored with flesh color, or light pink. Creamy yellow around eyes.

Sprouts: base creamy white to light lilac; leaf scales and tips pure mauve to magenta, color often absent.

Flowers: white; moderately free bloomer.

Group 7. *Burbank.*

Tubers: long, cylindrical to distinctly flattened, inclined to be somewhat spindle-shaped; skin white to creamy white, smooth and glistening or slightly netted, or deeply netted and dark russet in the case of section 2.

Sprouts: base creamy white or faintly tinged with magenta; leaf scales and tips usually lightly tinged with magenta but quite often color is absent.

Flowers: white; moderate bloomer.

Group 8. *Green Mountain.*

Tubers: moderately to distinctly oblong, usually broad, flattened with blunt ends; skin a dull creamy or light russet color; sometimes rather heavily netted especially toward the seed end.

Sprouts: section 1, base, leaf scales, and tips creamy white; section 2, base usually white, occasionally tinged with magenta; leaf scales and tips tinged with lilac to magenta; color usually very faint.

Flowers: white; blooms profusely.

Group 9. *Rural.*

Tubers: broadly round-flattened to short oblong, or distinctly oblong flattened; skin creamy white; usually smooth, but sometimes lightly netted; or heavily netted, and russet color as in section 2.

Sprouts: base dull white; leaf scales and tips violet-purple to pansy-violet.

Flowers: central portion of corolla deep violet-purple with the color growing lighter toward the outer portion; five points of corolla white or nearly so. Moderate bloomer.

Group 10. *Peerless.*

Tubers: round flattened to heart-shape flattened, usually heavily shouldered due to deep recession of stem; skin dull white or buff in section 1; distinctly russet or brownish color in section 2, or a deep bluish purple with occasional creamy white splashes, usually around the eyes in section 3.

Sprouts: sections 1 and 2, leaf scales, and tips usually faintly tinged with lilac; section 3, base, leaf scales, and tips vinous-mauve.

Flowers: white; blooms very sparingly.

Group 11. *Peachblow.*

Tubers: round to round flattened or round oblong; skin creamy white, splashed with crimson or solid pink; eyes bright carmine. Includes some early-maturing varieties.

Sprouts: base, leaf scales, and tips more or less suffused with reddish violet.
Flowers: purple; usually rather free bloomers.

Group 12. *Up-to-date.*
Tubers: oblong flattened to somewhat obovate flattened; skin creamy white, moderately netted or nearly smooth.
Sprouts: base dull white, leaf scales faintly to distinctly tinged with light magenta.
Flowers: rose-purple; moderate to fairly profuse bloomer.
Pistil: usually short, thick, and curved with enlarged stigma.

Each group in the above classification has been named from the variety within the group that most nearly represents the group as a whole and that is considered perhaps most important commercially. Not all of these groups are equally important, the Green Mountain and the Rural being produced extensively throughout the leading potato states, while the Early Michigan and Hebron are no longer very important anywhere.

The leading varieties, the season of maturity of varieties included, and the region of commercial importance of each group are given in Table XLV.

The choice of a variety for a given locality should be made on the basis of such factors as soil type, average growing season temperature, and market preference. Most of the varieties in each group are similar not only in vine and tuber characters, but also in respect to soil and climatic adaptation and susceptibility to disease. Thus the Green Mountain and the Cobbler groups require ideal growing conditions of soil and climate and are relatively susceptible to disease while varieties of the Up-to-date, Rose, Rural, and Peachblow groups are less affected by adverse environment and are more disease-resistant than other groups. In New York where climatic conditions are often favorable to the development of late blight, the Rural group is better adapted to the heavier soils than the Green Mountain. Such soils are more subject to baking under droughty conditions and more conducive to rot in the tubers in wet seasons; under these conditions, the Rural varieties have been found to rot less and to yield more than those of the Green Mountain group. Varieties of the Rural group also blossom and set tubers about 10 days to 2 weeks later than Green Mountain varieties. This difference might easily have a bearing on the comparative influence of weather on yield, between varieties of the two groups.

A variety to be popular on most markets today must have white-skinned tubers with few, shallow eyes and the tubers must be rather short, flat, and of high starch content. Colored-skinned, deep-eyed, elongated tuber varieties are no longer popular except in the case of some early varieties on a few markets.

The U. S. Department of Agriculture has carried on an extensive potato-breeding program designed to develop improved varieties since 1910. Most of this work has been done at Presque Isle, Maine, where condi-

TABLE XLV.—STANDARD VARIETIES, REGION OF PRODUCTION, AND SEASON OF MATURITY OF POTATO GROUPS

Group	Standard varieties	Season of maturity of varieties within the group	Principal region of production
1. Cobbler	Irish Cobbler Early Eureka Potentate Flourball	Early	New England, Middle Atlantic states, Virginia, the Carolinas, Iowa, and Prince Edward Island
2. Triumph	Bliss Triumph or Stray Beauty Quick Lunch or Noroton Beauty White Triumph Warba, Red Warba	Very early	Gulf states, Oklahoma, Arkansas, New Mexico, Minnesota, Wisconsin, North Dakota, and Nebraska
3. Early Michigan	Early Michigan Early Puritan	Early	Not important commercially
4. Rose	*Section* 1 Early Rose Early Thorobred Jersey Redskin Late Rose Evergreen White Rose	Early, medium, late, and very late	Northeastern U. S. mainly
	Section 2 Early Manistee Improved Manistee Late Manistee King or Spalding's Rose 4	Early, medium, and late	Florida, Maine, New York, Wisconsin
	Section 3 New Scotch Rose Seneca Beauty	Medium	Not important commercially
5. Early Ohio	Early Ohio Early Six-weeks Ohio Junior White Ohio	Very early	Red River Valley of Canada, Minnesota, and North Dakota, Montana, Kansas and Nebraska
6. Hebron	Beauty of Hebron Early Bovee Crown Jewel New Queen	Early and medium	Not commercially important. New England and Middle Atlantic states mainly
7. Burbank	*Section* 1 Burbank or Burbank Seedling Pride of Multnomah *Section* 2 Russet Burbank California or Colorado Russet Netted Gem	Medium	Pacific coast and Intermountain states and irrigated lands of the West

Table XLV.—Standard Varieties, Region of Production, and Season of Maturity of Potato Groups.—(*Continued*)

Group	Standard varieties	Season of maturity of varieties within the group	Principal regions of production
8. Green Mountain...	Green Mountain Norcross Carman No. 1 State of Maine Gold Coin Mill's Pride or Mill's Prize Delaware	Medium	Ontario, Quebec, and maritime provinces of Canada, New England and Middle Atlantic states, Michigan Wisconsin, and Minnesota
9. Rural.............	*Section* 1 Rural New Yorker No. 2 Carman No. 3 Sir Walter Raleigh Number 9 Heavyweight Pioneer Rural *Section* 2 Dibble's Russet Late Petoskey Russet Rural	Late	New York, Pennsylvania, Ohio, Michigan, Wisconsin, Minnesota, and Colorado
10. Peerless...........	*Section* 1 Pearl or Peerless *Section* 2 Peoples *Section* 3 Blue Victor	Medium and late	Colorado, Idaho, and adjacent states Maine, Pennsylvania
11. Peachblow........	*Section* 1 Early Peachblow Jersey Peachblow McCormick *Section* 2 Perfect Peachblow Red McClure White Peachblow	Early, medium, and late	Colorado, Maryland, Virginia, North Carolina, and South Carolina
12. Up-to-date........	Up-to-date Bull Moose Idaho Rural Charles Downing British Queen	Late	Pacific coast states, British Columbia, New York, Kentucky, and Indiana

tions for flowering and hybridizing are very favorable. The aim has been principally to develop varieties resistant or immune to the mild mosaic disease, resistant to late blight, of desirable habit of growth, and of good culinary and market quality. They have been successful in these objectives. The first two new varieties, Katahdin and Chippewa, were named in 1923. Since then Houma, Earlaine, and Sebago have been introduced. All five of these are resistant to mild mosaic and bear tubers that are very white, shallow-eyed, and of desirable shape. In addition to these characters, Sebago is also resistant to late blight. In season of maturity, Earlaine and Chippewa are early, Houma is midseason, and Katahdin and Sebago are late. All have a fairly wide adaptation, Chippewa and Katahdin being especially well adapted to muck soils. Chippewa generally outyields Cobbler and is gradually superseding the older variety.

About 1929, the Minnesota Experiment Station introduced a new early variety named Warba. It was developed to fill the need for an earlier and better adapted variety than Cobbler for the Red River Valley. It is very early and somewhat resistant to mild mosaic but the tubers are rather deep-eyed and rather blocky and irregular in shape. Warba is well adapted to muck soils and for a first early crop in home gardens.

Most variety tests have been of very limited value because of (1) their short duration, (2) too few strains of the leading varieties concerned, (3) the very limited and local significance of the results, and (4) the exaggerated conclusions drawn. Strain tests of the leading standard varieties for a given region are of much more value, in that they assist the grower in locating and the experiment station in developing high-yielding seed stocks.

Relatively little significance attaches to potato variety names. Of most importance is the choice of a varietal type adapted to the particular soil, climate, and market and, thereafter, the choice of a high-yielding strain of seed of some standard variety of this type. Whether a strain of seed thus procured will remain profitable, depends upon its care and selection in both field and storage to maintain its yield and to protect it from disease.

Diseases.—The potato is probably subject to more diseases than most other vegetables. Only a few of these, however, are usually very serious in any one section of the country. Those that depend for their prevalence or severity on weather conditions may be serious one year and inconspicuous the next. Other diseases, not influenced by weather, may be present in more or less uniform degree every year. Some diseases are caused by fungi, some by bacteria, some by slime molds, and some others are presumed to be nonparasitic. Some attack the foliage only, some the tubers only, and some both. The majority of potato troubles present in this country have been introduced from Europe.

A classification of the principal potato diseases on the bases of type, portion of plant directly affected, regions of principal occurrence, method of hibernation, and principal control methods is given in Table XLVI.

The more prominent symptoms of, and the principal control measures for, a few of the most important potato diseases are discussed on pages 374 to 376.

TABLE XLVI.—A CLASSIFICATION OF POTATO DISEASES

Disease	Type	Portion of plant directly affected	Regions of occurrence in U. S.	Method of hibernation	Control measures
Late blight (*Phytophthora infestans*)	Fungous	Foliage and tubers	Northeastern U. S.	In seed	Bordeaux mixture or copper-lime dust
Early blight (*Alternaria solani*)	Fungous	Foliage	General	In trash in field	Bordeaux mixture or copper-lime dust
Fusarium wilt (*Fusarium oxysporum*)	Fungous	Foliage and tubers	General	In seed and soil	Clean seed and crop rotation
Verticillium wilt (*Verticillium albo-atrum*)	Fungous	Foliage and tubers	General	In seed and soil	Clean seed and crop rotation
Fusarium tuber rot (*Fusarium eumartii*)	Fungous	Tubers and foliage	General	In seed and soil	Clean seed and crop rotation
Yellow dwarf	Virus	Foliage and tubers	Scattered areas in U. S.	In soil and seed	Clean seed and crop rotation
Blackleg (*Bacillus atrosepticus*)	Bacterial	Foliage and tubers	Northern states and Canada	In seed	Clean seed and disinfection of cutting knife
Wart (*Synchitrium endobioticum*)	Fungous	Tubers	Mining districts of Penna. mainly	In seed and soil	Long crop rotation and immune varieties
Silver scurf (*Spondylocladium atrovirens*)	Fungous	Tubers	General	On seed	Clean seed and crop rotation
Rhizoctonia (*Corticium vagum*)	Fungous	Tubers, new sprouts, and base of stems	General	On seed and in soil	Clean seed, crop rotation, and seed treatment
Common scab (*Actinomyces scabies*)	Bacterial or fungous	Tubers	General	On seed and in soil	As for rhizoctonia
Powdery scab (*Spongospora subterranea*)	Slime mold	Tubers	Very slight in northern states and Canada	On seed and in soil	As for rhizoctonia
Spindling sprout	Nonparasitic	Sprout growth from tubers	General	Seed	Seed selection and good storage
Mosaic	Virus	Foliage	General	In seed	Seed from clean fields and insect control
Spindle tuber	Virus	Foliage and tubers	General	In seed	As for mosaic
Leaf roll	Virus	Foliage	General	In seed	As for mosaic
Tipburn	Physiological	Leaf tips and margins	General	None	Bordeaux mixture as for blight
Hopperburn	Insect	Leaf margins	General	None	Same as for tipburn
Arsenical injury	Physiological	Leaves burned by free arsenic	Where improperly made arsenical sprays used	None	Use excess of lime with arsenical
Net necrosis	Virus	Tubers	General	In seed	As for leaf roll
Black heart	Physiological	Tubers	General	None	Proper aeration in storage
Hollow heart	Physiological	Tubers	General	None	Not known

Late Blight (*Phytophthora infestans*).—This is probably most serious of all potato diseases. It is most serious in wet seasons, since moist conditions are necessary for the germination and spread of the spores of the causal organism. It attacks the foliage at any point and is not confined to the margins or tips of the leaves as in tipburn. The latter is very often confused with blight by even experienced growers. Blight-affected areas on the leaves are water soaked in appearance and usually show a whitish mold around the margin of the affected area on the under surface. Since the blight organism does not live over in the soil nor on dead tissue, the initial infection is from the seed tuber, which shows the disease in the form of a reddish-brown dry rot. Spores from the affected stem may come in contact with new leaf growth and thereafter spread from plant to plant or from field to field by wind, rain, or other carriers. Thorough spraying under high pressure every 10 days to 2 weeks with 5–5–50 Bordeaux mixture is necessary to insure complete protection from the disease. It is a mistake not to spray before rains because rain is usually responsible for the infection and spread of the causal organism. Spraying with not less than 200 pounds pressure will insure efficient control. Tubers are rotted by late blight as a result of the spores being washed down through the soil during rainy periods late in the growing season. Ridging is, therefore, one means of protecting tubers from the blight rot.

Rhizoctonia (*Corticium vagum*).—This disease is present on the skin of the tuber and is very general in occurrence but, because of its resemblance to dried muck or dirt, it is commonly overlooked. Although it does not affect culinary quality, it is often very serious on seed because when planted with the seed piece, the fungus may so girdle the new sprout as to prevent its reaching the surface of the ground. Late or weak hills, as seen early in the summer, are commonly the result of this girdling. Soaking the seed before cutting, for 1½ hours in corrosive sublimate at a strength of 4 ounces to 30 gallons of water will kill the fungus on the tuber. Crop rotation is also recommended.

Common Scab (*Actinomyces scabies*).—Although as widespread as any other disease, it affects mainly the marketability of the crop. The irregular shaped, russet lesions on the surface result in waste and may in severe cases make the tubers almost worthless. This disease is similar to Rhizoctonia in respect to its method of hibernation and control. Unlike the latter, however, the causal organism is favored by soil less acid than pH 5.6. The use of lime or stable manure on soil soon to be used for potato growing should be avoided.

Wilt (*Fusarium sp.*).—The name wilt is given to this disease because it causes a rapid wilting or collapse of the plant usually late in the growing season. The fungus enters the roots or stolons and becomes localized in the vascular tissues, thereby killing this tissue and eventually stopping further sap flow. The base of the plant dies first with a progressive wilting toward the top. A cross section of either tube or base of the stem will usually show the disease in the form of dead tissue in the vascular area. Apparently, infection may come either from the soil or from affected seed. In cutting seed, all tubers showing discoloration at the stem end should be discarded.

BLACKLEG (*Bacillus atrosepticus*).—This disease derives its common name from the fact that the causal bacteria produce a soft black decay on the base of the stem and at the stem end of the tuber. The disease is favored by cool weather and is seldom found outside of the maritime provinces of Canada, Maine, and other New England states. It does not appear likely to become serious in the potato states farther south. Like many other bacterial diseases, it spreads by insects and contact in circular areas outward from the initial point of infection in the field. Affected plants first show a yellowing in the upper leaves and later a complete killing of the plant. Seed treatment as for common scab, the use of clean seed from uninfected fields, and the early elimination of affected plants in the field are the principal control measures.

MOSAIC.—A blotching or mottling of the normally dark green leaf with light green areas often accompanied by more or less crinkling or cupping of the leaf surface are typical symptoms. Mosaic, spindle tuber, yellow dwarf, and leaf roll are classed as virus diseases. Mosaic is carried over to succeeding generations in the seed tuber although the latter shows no evidence of abnormality at any time. By virtue of the abnormal chlorophyll development in the leaves and the reduced leaf area in a mosaic plant, the yield is reduced approximately one-third on the average. Although most standard varieties are susceptible to the disease, it is most serious in the Triumph and the Green Mountain groups. Transmission is mainly by the potato aphis, *Myzus persicae*, and leaf hoppers which inject the juice of infected plants into healthy plants. Control consists in the use of seed from clean fields, in the control of the insects named, and in the use of an isolated seed plot to prevent contamination of seed stock by close proximity to diseased fields.

LEAF ROLL.—This is a virus disease so-called because its principal symptom consists in the upward rolling of the lower leaves of the plant. The plant is usually, though not always, smaller than normal, of a paler color, and of an abnormally upright or clumpy habit of growth. The leaves are not only rolled but also unusually thick and leathery due to the accumulation of starch which in a normal plant is translocated down through the stolons for tuber production. A similar rolling of the upper leaves only on the plant is not a true criterion of the disease. Leaf roll is even more serious than mosaic in that it reduces the yield on an average by two-thirds. Its mode of transmission, method of hibernation, and control are apparently identical with those of mosaic. All standard varieties, however, seem to be equally susceptible to the disease.

SPINDLE TUBER.—This is a virus disease of comparatively recent occurrence in America. In its effect on yield and its method of transmission and control, it is similar to leaf roll. In fact, the disease has been termed marginal leaf roll. The symptoms are evident on both foliage and tubers. The affected leaves frequently are rolled upward at the margins which are usually crinkled. The terminal leaflet is usually twisted and partly overlapped by the two adjacent leaflets. The leaves are usually smaller, and darker green than those of healthy plants. The stolons are not foreshortened as in common leaf roll. The tubers are elongated and have more numerous and more conspicuous eyes than those of healthy plants.

YELLOW DWARF.—This virus disease was first reported in New York in 1917 but has since been found in a few other eastern and southern states. Its name is derived from the fact that affected plants first show a yellowish color and a foreshortening of the growing tips of the upper foliage and often a decided dwarfing of the plant. The tubers are usually worthless, being much cracked, ill-shaped, and showing brown necrotic spots in the flesh. The disease is seldom found to affect over 5 per cent of the plants in any one field and most of them are not worth harvesting. The common clover leaf hopper has been found to be the carrier of the virus, hence infection may be largely avoided by not planting potatoes in close proximity to fields of red clover.

Insects.—There are six insects considered important in the extent to which they affect the potato crop. Some of these affect the foliage only, some the tubers only, and some both. Only these six are discussed here.

COLORADO POTATO BEETLE (*Leptinotarsa decemlineata* Say).—This insect is found throughout this country but it is much more serious in the East than in the West. The adult beetle is oval in outline, about $\frac{3}{8}$ inch long, and has ten black stripes running lengthwise over its yellow, hard wing covers. Being first found in the Rocky Mountain section of eastern Colorado about 1856, it rapidly traveled eastward reaching the Atlantic coast about 1874 and Nova Scotia, Canada, about 1882. It is a leaf-eating insect, most of the damage being done by the larvae which hatch from clusters of orange-colored eggs deposited on the underside of the leaves. The tubers are not affected except indirectly through a reduction in yield because of a reduction in foliage. The minimum life cycle is about 4 weeks, more than one generation a season being possible. The insect overwinters as the adult beetle in the soil.

Control consists in the application of arsenical sprays to the foliage, the more commonly used being Paris green, arsenate of lead, and calcium arsenate. Spraying is most efficient if applied immediately after the larvae hatch. Paris green and calcium arsenate will, unless properly diluted with water or Bordeaux mixture or neutralized with lime, cause injury to the leaves. This is not true of arsenate of lead. The latter is also less likely to be washed off the foliage than the other arsenicals. Paris green is usually applied 1 pound to 50 gallons, calcium arsenate 2 pounds to 50 gallons, and arsenate of lead 4 pounds to 50 gallons of water.

FLEA BEETLE (*Epitrix cucumeris*).—The flea beetle is of very general occurrence. The adult is a jet-black, shiny, hard-shelled beetle about 1⁄16 inch long which eats tiny, round holes through the leaves. In severe cases, the leaves are reduced to a sievelike structure and the yields of tubers thereby much decreased. The larvae occasionally damage the tubers by mining into them sufficiently to cause what are called pimply potatoes. The flea beetle overwinters in trash or leaves as an adult, emerges in May or June, and lays its eggs near the roots of the plant. There is usually but one brood in a season. Control consists in thorough spraying with Bordeaux mixture which acts as a repellent.

LEAF HOPPER (*Empoasca fabae*).—This is a leaf-sucking insect which works mainly on the under surface of the leaves. It is a small, elongated, pale-green insect about 1⁄10 inch long which hops or flies actively from plant to plant. In dry seasons, it may so suck the plant of its juices as to cause much dead tissue at the margins and tips of the leaves. This form of injury is commonly recognized as tipburn or hopperburn. It passes the winter in either the adult or the egg form. The nymphs from the winter eggs appear early in the spring and begin feeding at once. There may be from two to five broods in a season. The only effective control yet devised is the use of Bordeaux mixture as a repellent. Spraying of both upper and lower surfaces of the leaves is considered essential. The addition of nicotine sulphate to the regular Bordeaux formula has resulted in quicker control, but the added cost of the nicotine sulphate may not be justified (Dudley 1921). Recently work in Ohio (DeLong, 1929) has shown that leaf hoppers are measurably controlled by Bordeaux in that the copper from this fungicide is absorbed by the potato leaf, and this in turn is toxic to the hopper as it sucks the sap from the under surface of the leaf.

POTATO APHIS (*Macrosiphum solanifolii*).—This insect has become a serious potato pest in certain areas in recent years. It is a relatively large plant louse occurring in either pink or green body color and in both winged and wingless forms. As a sucking insect like the leaf hopper, it works on the under surface of the leaves and on the more tender stem portions of the plant. As the injury progresses, the leaves tend to curl downward and both stems and leaves show irregular, brownish areas from which the juice has been sucked. In dry seasons large circular areas in fields and sometimes whole fields may be prematurely killed by this insect. Patch (1925) has furnished evidence that the rose is the primary host plant on which the aphis lays its overwintering eggs and on which the first generation feeds in the spring. Part of this generation is wingless and part winged, the winged individual flying to the potato fields during June or July, after which other generations develop rapidly. Serious losses result in yields not only from direct injury to the plant, but also from the fact that potato mosaic is mainly disseminated from diseased to healthy plants by this insect. The aphis is difficult to control first, because it works mainly on the underside of the leaves and second, because its presence is usually not detected until damage has resulted and it has become well established. Spraying with nicotine sulphate or "Blackleaf 40" as a contact spray and the elimination of wild rose bushes in the locality are recommended.

WHITE GRUB (*Lachnosterna species*).—The white grub commonly called June bug or May beetle annually causes considerable loss by the larvae so eating the surface of the tubers as to decrease their market value. In severe cases only, potato plants may collapse because of injury to the roots, stolons, or bases of the stems. The insect is most common in fields which for several years previous have been in sod. The larvae feed mostly on grass roots and when these are not near by they attack the potato tubers. The life cycle is 2 to 3 years, the larva usually requiring 2 years to become full grown. Tuber injury is done mainly by the larvae in their second year. Although white grubs are abundant about every 3 years, predictions as to when grub years will occur are not always reliable. The years 1921, 1924, and 1927 were so-called grub years, much damage being reported for 1921 in Iowa, Minnesota, New York, Connecticut, and New Jersey. When it is feasible to use old sod land for potatoes, it should be fall-plowed in order that the grubs and the beetles may be killed by winter freezing. Otherwise, some crop other than potatoes should follow sod.

WIREWORMS.—The adult of the wireworm is the common click beetle. It is probably as common as, and even more serious than, the white grub. The larvae, known as wireworms because of their long, hard, cylindrical bodies, eat their way often deeply into the tuber and thus render it worthless for human consumption. The life cycle is from 3 to 5 years, the larvae requiring somewhat longer to mature than the white grub. It varies in length from ¼ to 1 inch depending mostly upon its age. Its habitat and methods of control are similar to those given for white grubs. The adult beetle of the wheat wireworm usually deposits its eggs during May and early June in moist, cool soil. Such conditions are found in wet, poorly drained places in the field and in fields occupied by seedings of clover, timothy, winter wheat, or rye. This means that safety from wireworm injury is best attained by not planting potatoes in fields previously occupied by these crops during the egg-laying period.

Harvesting.—Except in the northernmost sections of the northern potato states, the main or late crop is not dug until the tubers are mature. Due to the short growing season in Aroostook County, Maine, and in some other northern sections, the foliage is often killed by frost before maturity. The immature tubers from these sections, as well as tubers from the early crop in some other states, can be recognized in the market by their peeled, chafed, and curled skins. Although this immaturity is considered desirable in seed potatoes, it is less desirable from the standpoint of eating quality. Since yield increases rapidly during the last stages of maturing, the crop should not be dug until the foliage is entirely mature. The only exception to this rule is in the event that early market prices are so attractive as to make a certain amount of sacrifice in yield feasible. The rate of increase in yield at various periods up to complete maturity is well illustrated in the results obtained by Kohler (1910) as shown in Table XLVII.

Table XLVII.—Results from Digging Early Ohio Potatoes at Intervals during the Period of Development at the Minnesota Station (1909)

Date of digging	Gain in bu. of marketable per day	Yield in bu. per acre		Per cent of foliage dead
		Marketable	Total	
July 31	...	10.9	38.7	0
August 7	7.5	62.3	87.7	1
August 14	7.6	115.4	141.5	8
August 23	7.2	182.1	203.2	22
August 30	6.4	226.8	253.8	99

Weather plays an important part in determining time of harvest because it is desirable from the standpoint of disease and keeping quality that the tubers go into storage in a clean, dry condition. Digging the crop before maturity in order to avoid tuber rot when the late blight has appeared is a serious mistake. Tubers so dug are brought in contact with the active blight organism on the foliage and will almost surely rot worse in storage than as if they had remained in the soil until all green foliage was dead. Potato tubers keep better and bruise and peel less if allowed to remain on the ground after digging for an hour or two until the skin "sets."

Although in some sections, the crop is still dug by hand, chain-elevator diggers are common wherever topography is not too rolling and stones not too numerous to prevent their use. Such machines permit of harvesting from three to five times more acreage in a day than is possible with hand digging. With either hand or machine digging, a certain amount of bruising seems unavoidable.

Potatoes are commonly picked up by hand into slatted crates of one bushel capacity, hauled in these to storage and stored in this way, or else dumped into piles. In some sections, splint baskets are used instead of crates and these cause less bruising and are easier to handle.

Grading.—Since it is easier to judge appearance than eating quality in market potatoes, appearance is the more influential factor in price determination. The advantage of some system of uniform grading both as to size of tuber and skin character is, therefore, obvious. Growers are slowly beginning to realize that it does not pay to ship and pay freight on ungraded stock containing dirty, undersized, and misshapen tubers. Such stock is evenly graded before it reaches the consumer and, as a result, the handling costs deducted by the middlemen are greater, the growers' receipts less, and the consumers' cost more. In addition, the cull stock removed in the grading process is wasted, whereas it would have some value as stock feed if left on the farm.

Standard grades for potatoes were recommended by the U. S. Department of Agriculture and the U. S. Food Administration in 1917. These grades were made mandatory by the Food Administration from January to December in 1918. They have become so popular that many growers are voluntarily using them and many states have established them as their official standards. These grades as revised by the Bureau of Agricultural Economics, U. S. Department of Agriculture in 1933 are as follows:

U. S. No. 1 shall consist of potatoes of similar varietal characteristics which are fairly well shaped, free from freezing injury, blackheart, and soft rot or wet breakdown, and from damage caused by dirt or other foreign matter, sunburn, second growth, growth cracks, air cracks, hollow heart, cuts, shriveling, sprouting, scab and blight, dry rot, rhizoctonia, other diseases, insects, or mechanical or other means.

Unless otherwise specified the diameter of each potato shall be not less than 1⅞ inches. Tolerance 5 per cent.

In order to allow for variations other than size incident to proper grading and handling, not more than 6 per cent of the potatoes in any container may be below the requirements of the grade but not to exceed one-sixth of this amount or 1 per cent shall be allowed for potatoes affected by soft rot or wet breakdown. In addition, not more than 5 per cent may be damaged by hollow heart.

U. S. Commercial shall consist of potatoes that meet the requirements of U. S. No. 1 grade except that they shall be free from serious damage by dirt and except for the increased tolerance for defects specified below.

Unless otherwise specified, the diameter of each potato shall be not less than 1⅞ inches. Tolerance 5 per cent.

In order to allow for variations other than size incident to proper grading and handling, not more than a total of 20 per cent of the potatoes in any container may be below the requirements of this grade, but not more than 5 per cent may be seriously damaged by hollow heart and not over 6 per cent may be below the remaining requirements of U. S. No. 2 grade provided that not more than one-sixth of this amount or 1 per cent shall be allowed for potatoes affected by soft rot or wet breakdown.

U. S. No. 2 shall consist of potatoes of similar varietal characteristics which are free from freezing injury, blackheart, and soft rot or wet breakdown, and from serious damage caused by dirt or other foreign matter, sunburn, second growth, growth cracks, air cracks, hollow heart, cuts, shriveling, scab, blight, dry rot, other disease, insects, or mechanical or other means.

Unless otherwise specified the diameter of each potato shall be not less than 1½ inches. Tolerance 5 per cent.

In order to allow for variations other than size incident to proper grading and handling, not more than 6 per cent of the potatoes in any container may be below the requirements of the grade, but not to exceed one-sixth of this amount or 1 per cent shall be allowed for potatoes affected by soft rot or wet breakdown. In addition, not more than 5 per cent may be seriously damaged by hollow heart.

U. S. Fancy shall consist of potatoes of one variety which are firm, mature, bright, well shaped, free from freezing injury, blackheart, shriveling, sprouting, soft rot, or wet breakdown, and hollow heart, and free from injury caused by dirt or other foreign matter, sunburn, second growth, growth cracks, air cracks, cuts, scab, blight, dry rot, rhizoctonia, other disease, insects, or mechanical or other means.

The size of the potatoes may be stated in terms of minimum diameter or minimum weight, or of range in diameter or weight, or a certain percentage over a certain size, following the grade name but in no case shall the diameter of each potato of this grade be less than 2 inches and in addition, for long varieties such as Burbank, Russet Burbank, Early Ohio, Pride of Wisconsin, or other similar varieties, not less than 40 per cent of the potatoes in any lot shall be 6 ounces or larger in weight, and for round or intermediate shaped varieties such as Irish Cobbler, Bliss Triumph, Green Mountain, or other similar varieties, not less than 60 per cent shall be 2¼ inches or larger in diameter. Tolerance 5 per cent.

In order to allow for variations other than size incident to proper grading and handling, not more than 6 per cent of the potatoes in any container may be below the requirements of the grade but not to exceed one-sixth of this amount, or 1 per cent, shall be allowed for potatoes affected by soft rot or wet breakdown.

Unclassified shall consist of potatoes which are not graded in conformity with any of the foregoing grades.

Storing.—Some of the influences of temperature and humidity on stored potatoes have been discussed on p. 359. Good storage is as necessary to conserve quality and condition in table potatoes as to maintain vitality in seed. Statistics show that in the 35 late-potato states, between one-third and one-half of all merchantable stocks remain in storage up to Jan. 1. Of these, about 90 per cent is held by growers. This indicates the importance of farm storage in the northern states. Very little of the southern-grown crop is stored because of high average temperatures prevailing during the summer months, and the desire of growers to take advantage of early market prices. In the North, farm storage is of three principal types: house cellars, barn basements, and bank or underground cellars. House cellars are not usually ideal because of too high temperatures and too low humidity. Conversely, bank storage is most efficient because of low average temperatures, high humidity, and a minimum of temperature fluctuation.

The actual air temperature at which potatoes are injured by freezing is given by Wright (1927) as 29°F. However, he shows that this freezing point varies between varieties, and according to the temperatures under which the tubers have been previously stored. For example, potatoes previously stored at 50°F. had a freezing point 1°F. higher than similar potatoes previously stored at 32°F. Jones, Miller, and Bailey (1919) at the Wisconsin Station, studied the effects of low temperatures on internal tuber symptoms of injury. Varying degrees of injury were shown in the tuber flesh, these symptoms being necrotic tissue which the authors named "frost necrosis."

Smith (1933) reported the comparative weight losses of samples of potatoes stored for seven months of the 1930–1931 storage season in a bank storage, a barn basement, and a house cellar. The average shrinkage losses were 4.83, 5.43, and 5.64 per cent respectively. He concluded that "the greatest shrinkage losses of potatoes occur during the first month and the sixth and seventh months of storage. The shrinkage during the first month appears to be due largely to excessive evaporation and a high rate of respiration through the injured and uncorked surfaces of the tuber; whereas the increase in loss during the last two months occurs simultaneously with excessive sprout growth and increase in temperature." Numerous other investigators agree that these facts are common to most stored potatoes. When an exceptionally large volume is stored in piles, the temperature may rise so high and the aeration may be so poor as to cause physiological injury to the tubers at the bottom and center of the pile. This form of injury was termed "blackheart" by Stewart and Mix (1917).

Such storage factors as cost of labor, insurance on buildings, shrinkage, taxes, and interest on investment in the stored crop must always be taken into account. Whether to store or market the crop at harvest time should be determined by an estimate of whether or not prices are likely to increase or decline between fall and spring. Prices in the United States have usually increased toward spring in years of subnormal production and decreased in years of overproduction.

Table XLVIII.—Relation of Size of Potato Crop to Gross Returns According to Time of Selling

Size of crop	Crop year	Per capita production, bu.	Relation of time of selling to gross returns
Large (11)	1912	4.4	Early selling paid best.
	1917	4.3	
	1909	4.3	
	1914	4.2	
	1904	4.2	
	1922	4.1	
	1918	4.0	
	1906	3.9	
	1928	3.9	
	1920	3.8	
	1910	3.8	
Medium (11)	1924	3.7	Gradual selling was best policy.
	1923	3.7	
	1907	3.7	
	1902	3.7	
	1915	3.6	
	1927	3.5	
	1913	3.4	
	1908	3.4	
	1921	3.3	
	1905	3.3	
	1900	3.3	
Small (8)	1903	3.2	Late selling paid best.
	1919	3.1	
	1911	3.1	
	1926	3.0	
	1929	2.9	
	1925	2.8	
	1916	2.8	
	1901	2.6	

Marketing.—Early potatoes from Florida begin to move into northern markets in February, Carolina potatoes in May, Virginia potatoes in June, and New Jersey and Long Island potatoes in July and August. The late or main crop varieties are found in the leading markets from September to April. The late or main crop of potatoes comprises about 80 to 85 per cent of the total production. Late potatoes are found in our principal markets during all months of the year except July and August. The so-called late-potato states which led in carlot shipments in order of importance during the period 1922–1926 were Maine, Minnesota, Wisconsin, Michigan, New York, Idaho, and Colorado. According to Sherman, Fiske, and Park (1929), about 35 per cent of the crop produced in the 35 late-potato states annually was shipped to market in carlots during this 5-year period. In addition, about 29 per cent is marketed locally by motor truck, making a total of nearly two-thirds of the crop available for sale. Of the remainder, about 16 per cent is used on farms for food, 9 per cent is saved for seed, and 11 per cent is unfit for use as either food or seed. Carlot shipments are no longer a valid indication of the surplus marketed by such important potato states as New York, Pennsylvania, and New Jersey because of the increasing proportion of the crop marketed by motor truck.

The question of when to sell potatoes for most profit to the grower is best answered by attention to such factors as size of the total United States crop, perishability of the crop, and cost of storage. The first of these factors is by far the most important. The annual per capita production figure obtained by dividing total production by total population is usually a reasonably safe barometer of potato price prospects. During the 30-year period, 1900–1929, per capita production varied from 2.6 to 4.4 bushels as indicated in Table XLVIII.

According to Stuart (1923), our annual per capita consumption of potatoes is about 2⅓ bushels, a figure very much lower than that for western European countries. As a result of a survey of 287 farm and city families in New York, Hardenburg (1929) found the per capita consumption of 114 city families to be 3.5 bushels compared to about 7 bushels by 173 farm families in the same area in 1928–1929. By comparing the years 1925 and 1928, as very short and very large crop years respectively, he showed how a difference of $1.33 per bushel in the Dec. 1 farm price made an apparent difference of 0.64 bushels in the per capita consumption on farms where the surplus crop was grown in the 35 late-potato states.

Various marketing facilities are in use, the agency depending upon such factors as distance to cities, highway and railroad facilities, and the development of local or state cooperative selling organizations. Much of the crop is still sold by the producer to local trackside dealers who accept and store the crop in limited quantities in warehouses as the roads and markets warrant. From the local dealers, the crop often goes to commission merchants, then to brokers, then to wholesalers, and finally to the retailers. The number of marketing steps between the producer and the consumer is the principal factor influencing cost of marketing. Many local, county, and state producers' cooperative selling organizations have come into existence during the last few years.

Most potatoes are now shipped in 100-pound bags. Bag shipments result in less damage and shrinkage in marketing than bulk shipments and, as a result, return the grower a larger per cent of profit. Barrel and hamper containers are objectionable because of expense and breakage. Within recent years, small package containers have become popular in the retail trade. Paper-box containers and paper, cotton, and burlap sacks holding 15, 25, and 30 pounds and bearing fancy brands may now be found in most of the larger retail markets. Such packages naturally involve better grading and a fancier pack than are found in the larger containers and bulk shipments. A standard carload of potatoes contains 600 bushels.

Improvement.—As long as most potatoes in this country are grown and stored under temperatures too warm to be ideal and as long as such diseases as leaf roll, spindle tuber, and mosaic are prevalent, seed stock will tend to degenerate. Consequently, a certain amount of continuous effort for improvement is necessary. Since the potato is propagated asexually by tuber cuttings, improvement is accomplished mainly by what may be termed *clonal selection.* Clonal selection is, in turn, based on the fact of variation between strains within the variety, between hills within the strain, and between tubers within the hill. Thus the principal methods of improvement by seed selection have been termed (1) mass selection, (2) mass-hill selection, (3) pedigree-hill selection, and (4) tuber-unit selection. All these aim to accomplish improvement by increasing yield and by decreasing or eliminating disease. Of the above methods, the first is the least thorough and the slowest of results, the last the most thorough and the most expeditious.

In *mass selection,* tubers of ideal appearance are selected from the bin or mass for planting without regard to the yielding ability or health of the parent plant. Although this is a common practice, only a slight improvement may be expected from it. It is not possible to detect virus diseases nor yielding ability by the appearance of tubers.

Both *mass-hill* and *pedigree-hill selection* consist first of all in the selection during the growing season of healthy, high-yielding hills. This provides for the avoidance of virus diseases evident in the foliage and the choice at harvest time of the highest yielding hills. Hills so selected are used in planting a seed plat the following year. In *mass-hill* selection, all selected hills are thrown together and planted without regard to the future performance of each individual hill. Planting selected hills, each in a row by itself for further study and record, as in *pedigree-hill selection,* provides for the later elimination of such hill progenies as do not maintain the high-yielding ability of the parent hill.

Inasmuch as tubers within the hill vary just as hills within the strain, so selection of individual tubers for test, as in *tuber-unit selection*, provides for the saving of seed from the progeny of only such units as maintain desirable characters. A so-called tuber unit usually consists of the four hills planted from the seed cut from a single selected tuber. None of these methods requires the annual selection of hills from the main field. After the original selections are made, all further efforts are confined to the seed plot.

Growers' organizations for the inspection and certification of seed potatoes were started in 1914. Certified seed is seed which is certified to be practically free from disease and varietal mixture, to be reasonably true to type, and to be high yielding as based upon a certain number of field and bin inspections. Such seed has supposedly met a published standard of excellence. Copy of the exact record of condition in field and bin is usually made available to the trade. Seed inspection and certification aim primarily to accommodate the demand for seed of known qualities under limited guarantee.

CHAPTER XXIII

THE SWEET POTATO

The sweet potato is a very important crop in tropical and subtropical countries, as in Africa, India, China, Japan, Malayan Archipelago, the Pacific Islands, tropical America, and southern United States. In fact in the South it is of more importance and partially takes the place of the Irish potato in the diet. The sweet potato is often called "potato" in the South, and the potato is called "Irish potato" or "white potato." It is a standard food article in the South, being served baked, fried, candied, and as filling for pies.

Some varieties of sweet potatoes, especially those having a moist, soft texture when cooked, are often called "yams" to distinguish them from the dry-fleshed varieties. It is unfortunate that the term "yam" has been used in this connection since the true yam is an entirely different plant, belonging to the genus Dioscorea. These two plants are not even closely related.

Statistics of Production.—The sweet potato ranks next to the Irish potato in importance as a vegetable crop. The acreage, production, yield, and value of the sweet potato crop fluctuate considerably as is indicated by the figures given in Table XLIX.

TABLE XLIX.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF SWEET POTATOES GROWN IN UNITED STATES BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield per acre, bu.	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1918–1922	786,000	95.7	75,185	$1.35	$101,450
1923–1927	649,000	90.3	58,618	1.29	75,704
1928–1932	771,000	86.1	66,368	.90	60,041
1933–1937	900,000	83.4	75,079	.79	59,634

A large part of the sweet-potato crop is produced in the South. Nine states produced over 80 per cent of the acreage in 1937: Georgia with 114,000 acres; Alabama, 100,000 acres; Louisiana, 90,000 acres; North Carolina, 85,000 acres; Mississippi, 82,000 acres; South Carolina, 57,000 acres; Tennessee, 55,000 acres; Texas, 52,000 acres; and Virginia, 39,000 acres. Other important states include Arkansas, Kentucky, Florida, New Jersey, Oklahoma, Missouri, and California. A considerable part of the crop grown in the South is consumed at home and sold locally, but shipments to northern markets have increased in recent years, as methods of storage and handling improved.

History and Taxonomy.—The sweet potato is probably a native of tropical America and was carried to the islands of the Pacific very early. It was apparently known in China early in the Christian Era. It was probably cultivated by the natives on the American continent hundreds or perhaps thousands of years before the discovery of America by Columbus. Many varieties were in existence at that time. It was mentioned by Oviedo (1526) as being grown in the West Indies and was carried by him to Spain. It was known in Virginia in 1650, possibly earlier. It is now widely distributed and important throughout the world where the climatic conditions are favorable.

The sweet potato (*Ipomoca batatas* Poir.) belongs to the Convolvulaceae or morning glory family. It is a tuberous-rooted perennial. The stems are usually prostrate and slender, and the juice of both vines and roots milky. The blossoms resemble those of the common morning-glory, being almost white or pale violet in color.

Climatic Requirements.—The plant is tender and requires a long, warm growing season. It cannot be grown successfully in a region having less than 4 months' frost-free period, with warm weather and sunshine for a greater portion of this period. Even with a season of that length, the sweet potato does not produce a satisfactory yield unless the nights, as well as the days, are warm for a considerable portion of time.

The sweet potato is one of the most drought-resistant vegetables. In fact it will produce a fair crop without irrigation in semiarid regions, where most vegetable crops will not thrive at all. A moderate rainfall during the growing season is, however, desirable. In regions of scant rainfall, irrigation is profitable when the water is applied at the right time. Most of the water should be applied between the time the plants are set and the time when they practically cover the ground. Garcia (1909) reports that 6 to 10 irrigations at the Experiment Station in New Mexico produced good yields; also that if sweet potatoes are kept well irrigated and the surface soil moist the tubers are nearer the surface of the ground than if the surface soil is allowed to dry out too much. Light irrigations at frequent intervals are preferable to heavy irrigations at long intervals.

Soils.—A well-drained, sandy-loam soil with a clay subsoil is considered ideal for sweet potatoes, although the crop can be grown on a wide range of soils if the growing season is sufficiently long. They are sometimes grown on almost pure sand, and with a fair quantity of fertilizer, good yields are obtained. On very rich soils, the crop produces too much vine growth and the potatoes are likely to be too large and rough, which reduces their market value. On heavy clay soils the tubers are also likely to be rough and irregular in shape. It is best, therefore, to select a light soil. The crop is particularly adapted to newly cleared lands, such as the cutover pine lands of the South.

Good drainage is important in growing sweet potatoes since the crop does not do well when water stands around the plants. Planting on ridges is commonly practiced on much of the land in the South, mainly for the purpose of drainage.

Preparation of the Soil.—On deep soils there is a tendency for the roots to grow long and slender, therefore, deep plowing is not advocated. However, a depth of 6 to 8 inches is none too deep and is much better than 3 to 4 inches, which is the common depth of plowing on so many southern farms. After being plowed, the soil should be thoroughly prepared as for other crops. Because the sweet potato will produce a fair yield with poor preparation, too little attention is given to preparing the land for it.

On a large part of the farms growing sweet potatoes the plants are set on ridges. These are usually thrown up with a small plow, throwing two furrows together. The ridges should be as low and flat as the drainage conditions will allow since narrow, sharp ridges dry out more readily than wide, flat ones.

Starnes (1894) reports experiments in which a comparison of ridge and level culture was made. In 1893 plants grown on ridges 14 inches high produced at the rate of 272.75 bushels and those grown on the level 237 bushels to the acre. In 1894 the results were practically reversed. Under level culture the yield was 270.3 bushels and under ridge culture 237.2 bushels to the acre. Unfortunately Starnes does not state the character of the soil on which the experiment was conducted. The results on a sandy, or sandy-loam soil would undoubtedly be very different from those on a clay soil. On the former, level culture would show to much greater advantage than on the latter. Experiments at the Arkansas Experiment Station on a deep, level, well-drained, rich sandy soil gave results in favor of ridges 3 inches high, as compared with level culture and with ridges 6 and 9 inches high.

In a dry season the ridges would be a disadvantage, while in a wet one they would be advantageous. In regions of heavy rainfall, particularly where the land is not well drained, ridge culture is preferable to level culture.

Manures and Fertilizers.—Commercial fertilizers are commonly used in growing sweet potatoes since satisfactory yields are produced by their use. As the sweet potato gives better results than most other vegetable crops on soils deficient in humus, manure can be used to better advantage on other crops. Fresh manure causes a rank growth of vines and the development of large, rough roots. It seems best, therefore, to apply manure to other crops and to depend on fertilizers to furnish the elements that are needed for the sweet potato. While results of many experiments indicate that manure is of value in growing sweet potatoes, especially on soils deficient in humus, there are not many conditions under which it is profitable to buy it, at present prices, for use with this crop. Other vegetable crops will give more profitable returns for the manure. However, where manure is available and is not needed for other crops, it might be used with profit at the rate of 5 to 10 tons per acre. Results of experiments reported by Durst (1916) indicate that application of 10.56 tons of manure applied under the ridge produced a larger yield than the same quantity applied broadcast. In these experiments the manure would not have returned a profit if purchased at the prices prevailing in many cities.

Results of experiments reported by Geise (1929) and by Schermerhorn (1924) indicate that on sandy and sandy-loam soils potash is needed in large quantities. Geise's experiments, carried on in Maryland for 5 years, (1 year in one location, 2 years in a second location, and 3 years in a third) show that nitrogen (87 pounds of nitrate of soda and 200 pounds of dried blood) increased the yield 35.2 per cent over the unfertilized check plots; phosphorus (600 pounds 16 per cent superphosphate) increased the yield 37.7 per cent; and the combination of nitrogen and phosphorus increased the yield 32.4 per cent. Potash (200 pounds muriate) increased the yield 160.5; phosphorus and potash 179.1 per cent; nitrogen and potash 199.6 per cent; and the complete fertilizer increased the yield 187.4 per cent over the mean of the unfertilized check plots.

Schermerhorn shows that the quantity of nitrogen influences the shape of the sweet potato. Excessive quantities tend to produce long potatoes. As the percentage of nitrogen in a complete fertilizer increased, the length of the potatoes increased and the diameter diminished.

Phosphorus is used in relatively small quantities by the sweet potato and is amply supplied in any ordinary complete fertilizer. Vorhees (1898) states that 200 bushels of sweet potatoes, not including the vines, contain on the average 10 pounds of phosphoric acid, 30 pounds of nitrogen, and 55 pounds of potash.

While potash is removed in relatively large quantities it should be borne in mind that many soils are rich in this element. When sweet potatoes are grown on soils that are deficient in available potash, as on many sandy and sandy-loam soils, it is desirable to supply considerable quantities of this element. Schermerhorn has shown that on sandy loam and on fine sand in New Jersey it resulted in producing a shorter, more chunky sweet potato, as shown in Figs. 55 and 56. On the other hand, Boswell, Beattie, and McCowan (1938) reported results obtained on sandy-loam soils in South Carolina that are not in agreement with those of Schermerhorn. It should be noted, however, that in South Carolina the yields were not greatly increased by increasing the potash application. When the soil used is not deficient in available potash, one should not expect any marked effect on either yield or shape of sweet potatoes by applying potash in varying quantities. It is possible that in some of the experiments on sandy and sandy-loam soils the quantity of nitrogen and phosphoric acid applied was so small that they were more limiting than was potash.

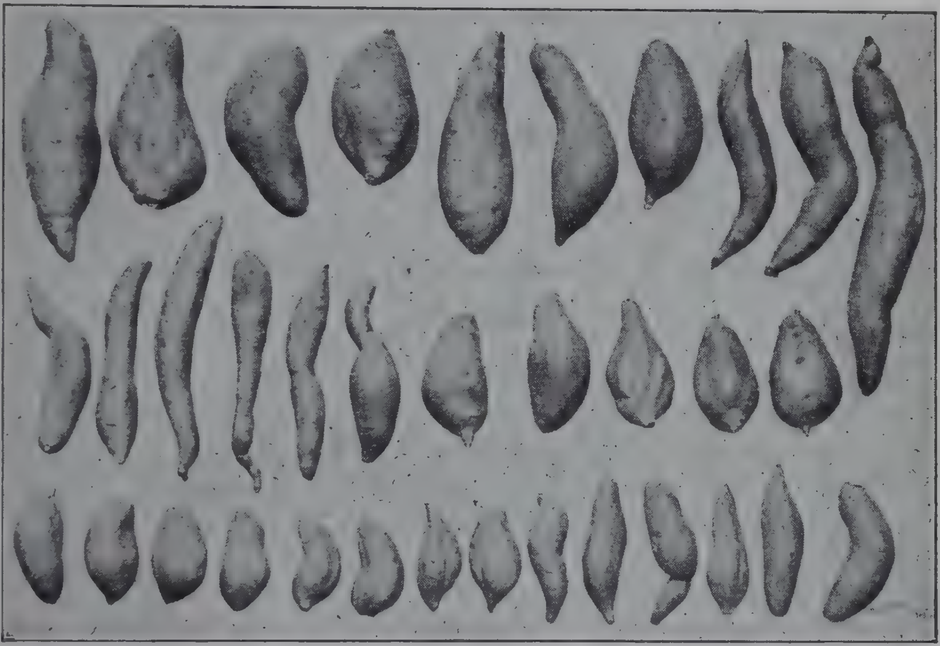

FIG. 55.—Sweet potatoes grown without potash fertilizer in Ocean County, N. J. Compare with Fig. 56. (*Courtesy of N. J. Agr. Exp. Sta.*)

The fertilizer practice varies greatly and no general recommendation can be given. Where the sweet potato is grown as a general farm crop in the South little fertilizer is used, but where it is grown as a truck crop more fertilizer is applied. Applications carrying 20 to 40 pounds of nitrogen, 60 to 100 pounds of phosphoric acid, and 80 to 100 pounds of potash are not uncommon. This is sufficient under most conditions. Unless experimental evidence shows that the soil contains sufficient available potash, it is desirable to supply this element on sandy and sandy-loam soils. In New Jersey the fertilizer recommended is 30 to 45 pounds of nitrogen, 80 to 120 pounds each of phosphoric acid and potash. Application of fertilizer in the row before making the ridge, or in bands beside the row, is preferable to broadcasting in most cases. When heavy applications of fertilizer are made, applying in the row is unsafe.

Where manure is not used, some humus-forming crop should be grown to turn under.

Propagation.—Sweet potatoes are grown either from plants or slips produced from roots, or from cuttings of the vines. In the northern sweet-potato sections a large part of the crop is grown from slips produced from sprouting seed potatoes in a hotbed. In the regions south of Virginia, the early crop for market is produced from slips, but a large part of the main crop is grown from vine cuttings. In this case enough roots are bedded, in an open bed, to produce slips for about one-eighth of the area to be planted. These slips are planted in the usual manner and, when the vines begin to run, cuttings are taken to plant the remainder of the field.

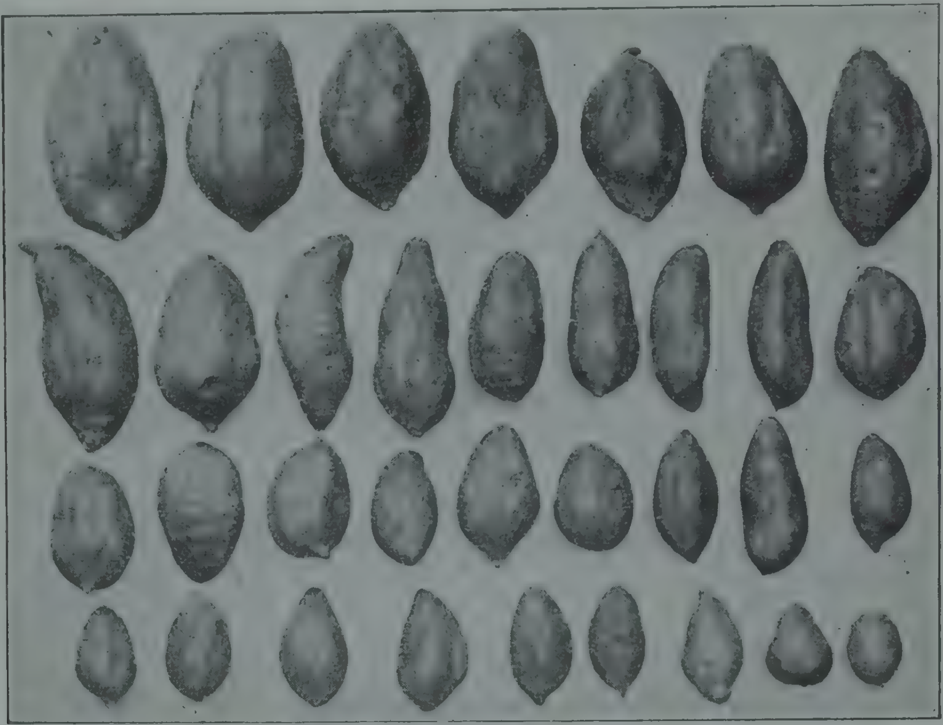

FIG. 56.—Sweet potatoes grown with a fertilizer containing 8 per cent potash in Ocean County, N. J. Compare with Fig. 55. (*Courtesy of N. J. Agr. Exp. Sta.*)

The growing season in the northern part of the sweet-potato region is too short for producing a commercial crop from vine cuttings, but this method is often used to grow seed roots for the following year. The vine cuttings have the advantage of being free from some of the serious diseases which are carried from the seedbed to the field on the slips. In the South, where the growing season is long, vine cuttings are preferable to slips for the main crop. The vine cuttings are cheaper, produce roots more nearly uniform in size and shape, and are less likely to carry disease. Experiments show that the yield from vine cuttings is as large, or even larger than from slips planted at the same time. In an experiment in Georgia, the yield was much larger from vine cuttings than from slips set July 28, 1913. In Arkansas the yields from slips and from vine cuttings were practically the same. The percentage of marketable potatoes was slightly greater from cuttings than from slips.

Growing the Plants.—When slips alone are used 6 to 8 bushels of seed roots are required to produce enough plants from the first pulling to set an acre, but if sufficient time is available to make two or three pullings 3 to 4 bushels of seed ordinarily will produce slips enough for an acre. The quantity of seed required depends on the size of the roots and the distance between the plants in the field. Large roots produce fewer plants from a bushel of seed than small or medium-sized roots. One bushel of good seed roots will produce 2,500 to 3,000 plants from two or three pullings, and should be given 20 to 24 square feet of bed space. Before bedding, the seed roots should be disinfected by treating for 5 to 10 minutes in a solution made by dissolving 1 ounce of corrosive sublimate in 8 gallons of water. After disinfection, the potatoes should be rinsed in clean water and placed in the sun to dry. This treatment will not kill the fungus within the potato, but will destroy any spores that may be on the surface. The solution should not be used more than two or three times since it loses its effectiveness after repeated use.

Open beds are usually made in a protected location, such as on the south side of a building or tight fence. The drainage should be away from the bed. An excavation is made 6 to 12 inches deep, 5 to 6 feet wide, and as long as needed for the quantity of potatoes to be bedded Manure is sometimes used to furnish a little heat to start the sprouts; in this case a depth of 12 inches is none too much. If manure is not used a depth of 6 inches is sufficient. About 4 inches of sand or loose soil is placed over the manure or on the bottom of the bed and leveled. The potatoes are then placed by hand as close together as practicable without allowing them to touch. They are then covered to the depth of an inch or two with sand or soil. The bed is watered thoroughly by sprinkling with a hose or watering can. As soon as the plants come through the surface more sand or soil is added, in order to develop a good root system. Straw, hay, leaves, or other litter is sometimes placed on the bed to prevent rapid drying of the surface and to protect it from cold. This covering should be removed as soon as the plants break through the surface of the soil to avoid soft, tender growth.

Hotbeds are used for growing sweet potato plants in the North and for a very early crop in sections of the South. All methods of heating are used including the use of manure, steam, hot water, and hot air. The flue-heated hotbeds are the most common, especially in those regions where hotbeds are not employed for growing other plants. The methods of construction and management of hotbeds are discussed in Chap. VIII.

The temperature of the soil in the hotbed should be 80° or 85°F. at the time the seed is bedded, and should fall gradually until it reaches 70° or 75°F. A high temperature favors rapid, soft growth and a low temperature delays sprouting and may even prevent it completely. At the proper temperature 6 weeks is sufficient time to grow plants large enough for setting out.

As soon as the potatoes are bedded and covered with soil, the bed should be watered. Later waterings should be given as needed. More water is required when steam, hot water, or furnace heat is used than when manure is used to supply heat. After the plants are up and the beds are left uncovered during the day, frequent watering is necessary.

Planting.—The sweet potato plant is tender and will not withstand a frost, therefore planting should be delayed until the danger of frost is past. In regions having a relatively short-growing period it is advisable to set the plants as early as weather conditions will allow. For an early crop in the South early planting is also desirable. For the main crop in most sections of the South planting in May and June usually gives better results than earlier planting. Experiments by Stuckey (1915) in Georgia with the Pumpkin Yam variety show the heaviest yield from planting on June 11 one year, May 16 the next year, and May 20 two years later. In some regions vine cuttings are planted in July and even as late as the first part of August with satisfactory results. Good yields need not be expected with less than 4 months' growing season.

With hand planting it is desirable to set the plants when the soil is wet so as to avoid the extra labor and expense of applying water. If the soil is dry when the plants are set, water should be used if at all practicable. If watering is not practicable the plants should at least be dipped in a thin paste made with mud and water to prevent the roots from drying out before being set and to make the soil adhere to them. This is called "puddling" and is usually done as the plants are pulled from the bed. The paste should not be allowed to dry on the roots as this would prevent them from coming into contact with the soil and delay growth. After puddling the roots, the plants should be kept covered with burlap, old carpets, blankets, hay, straw, or material which is kept moist.

The spacing of sweet-potato plants varies between wide limits depending on the variety and richness of the soil. Varieties that produce long vines are given more space than those with short-vine growth; on a rich soil more space is usually given than on a poor one. For varieties producing medium- to long-growing vines, the rows are spaced 4 to 6 feet apart and the plants are set 12 to 18 inches apart in the row, 15 inches being a common distance. Varieties producing short vines are planted in rows 3 to 4 feet apart in most regions. On the eastern shore of Virginia and in some other regions the plants are set 16 to 22 inches apart in rows about 30 inches apart for the Yellow Jersey variety. Sometimes when the plants are set 22 inches apart in the row two slips are set in each hill. In New Jersey the rows are spaced 2½ to 3 feet apart with the plants 22 to 30 inches apart in the row for cultivating both ways. If cultivation is to be in only one direction, the plants are spaced 18 to 25 inches apart. Experiments in Louisiana for 3 years resulted in favor of setting the plants 18 inches apart. The yields of merchantable potatoes per acre was 252 bushels for 8-inch spacing, 258.31 for 12 inches, 275 for 15 inches, 281.82 for 18 inches. Experiments in Georgia for 1 year showed a larger yield for plants set 18 inches apart than for those set either 24 or 30 inches apart. In the Georgia experiment, the Southern Queen and Pumpkin Yam varieties were used.

Sweet potato plants are set by hand or by transplanting machinery. When planted by hand the various methods described in Chap. IX are used. Wooden tongs, with which the plants can be caught by the root and thrust into the soil, are used by some growers. The tongs cannot be used alone to good advantage unless the soil is well prepared and is loose at the time of setting. An implement known as a "shovel," consisting of a piece of lath sharpened to a flat point, is sometimes used in connection with the tongs. This is used to open the hole for the plant. The operator carries the tongs in the left hand and the shovel in the right. Vine cuttings are usually pressed into the soil with a long notched stick. The cuttings are dropped at the proper distances and the planter places the notch of the stick over the middle of the cutting and forces it into the soil to the depth of 3 or 4 inches. With any of the hand methods of setting plants or cuttings it is important to pack the soil around them to prevent rapid drying.

Cultivation.—The methods of cultivating sweet potatoes are not very different from those employed with other farm crops. In a large part of the South they receive less cultivation than most other vegetables; in many instances less than cotton and corn. They should, however, be cultivated often enough to keep the weeds under control. Cultivation is done with one-horse cultivators, sweeps, or with gang cultivators drawn by two horses. As a rule the soil is worked toward the row to widen the ridge. Cultivation should be continued until the vines meet in the middle, but after this no attention is needed except to pull the large weeds by hand.

Difference of opinion exists regarding the advisability of moving the vines so that cultivation can be continued late in the season. Many growers turn the vines first to one side of the row and then to the other while cultivation is going on. Experiments by Starnes in Georgia indicate that disturbing the vines reduces the yield. The yield of sweet potatoes of the Pumpkin Yam variety was 270.3 bushels to the acre from plants not disturbed, while only 156.3 bushels was produced from vines which were not allowed to root at the joints. This experiment was conducted for only 1 year, hence is not conclusive. Newman in Arkansas conducted similar experiments for 2 years with the following results: vines moved for cultivation yielded 166 bushels, while those not moved produced 170.85 bushels per acre; vines lifted once a week produced 160.50 bushels and those not lifted produced 169.45 bushels per acre. Where the vines were moved for cultivation two more cultivations were given than when they were not disturbed. While the difference in yields from plants not moved and those that were moved is not great, it seems safe to say that disturbing the vines after they have grown to considerable length is not justified and is likely to reduce the yield.

Pruning the vines has been followed by some growers with the idea that keeping down foliage growth stimulates development of roots. Results of experiments by Garcia (1909) in New Mexico and Starnes (1894) in Georgia indicate that cutting back the vines materially reduces the yield. In New Mexico the experiments were carried on for 2 years with results as follows: hills pruned back to 12 inches in diameter produced 6,012 pounds to the acre; those pruned back to 24 inches produced 8,690 pounds; those cut back to 36 inches produced 10,857 pounds; and the plants not disturbed produced 16,520 pounds of potatoes to the acre. In Georgia the undisturbed plants produced 201.3 bushels per acre, plants pinched back weekly to 2 feet throughout the season produced 104.9 bushels, and those cut back weekly to 2 feet after Sept. 1 produced only 50.1 bushels to the acre. While the experiment in Georgia was carried on for only 1 year the results are so striking that they are worth considering. The very small yield from the plants that were cut back after Sept. 1 may have been due to the fact that only the older leaves were left on the vines. The plants that were cut back throughout the season had undoubtedly developed new vines and new leaves from the older branches and from the main stem of the plant. These new leaves would be much more active than the older leaves on the vines cut back after Sept. 1.

Varieties.—There are, at least, 200 names given to the varieties of sweet potatoes grown in the United States, but not over 40 true varieties exist. Not over 10 are of commercial importance and 5 of these constitute the bulk of the commercial crop.

Various attempts have been made to classify varieties of sweet potatoes. Price (1893) classified them into three groups based on the shape of the leaves. He then described each variety, but as no key was given except that referring to the shape of the leaves it is impossible to determine a variety if the name is doubtful or unknown. Groth (1901) worked out a system based on shape of leaf, size of leaf, length of stem, color of stem, size of stem, presence of star, color of lower surface of veins, arrangement of hairs on upper and lower surface of leaves, outside color of tubers, color of flesh, and distinctness of wood elements in tuber. This system is a great improvement over the one advanced by Price but, since some of the characters used vary greatly under different conditions, they are not entirely reliable. The terms "size of leaf," "size of stem," and "length of vine" as used by Groth are not reliable characters since the richness of the soil and the weather conditions greatly influence all of these. Some of the varieties described as having short stems (under 4 feet) grow to a length of 6 to 10 feet in nearly all regions where they are grown commercially.

The latest and perhaps the most complete system of classification is that published by Thompson and Beattie (1922). Under this system the varieties showing a marked similarity are grouped together in eight well-defined groups, each being distinct and easily recognized. By means of a simple key the group to which any variety belongs can be determined. Each group has been given the name of the most widely known, or the most typical, variety. Three of the large groups have been divided into sections to simplify the procedure of identification. The key to the groups is as follows:

- I. Leaves deeply lobed or parted (1 and 2).
    - 1. Leaves with deep purple stain at base of leaf blade—Ticotea group.
    - 2. Leaves without purple stain at base of leaf blade—Belmont group.
- II. Leaves not deeply lobed or parted (1 and 2).
    - 1. Leaves with purple stain at the base of leaf blade (A and B).
        - A. Stems purple or greenish with a decided tinge of purple—Spanish group.
        - B. Stems green (*a* and *b*).
            - (*a*) Leaves entire to slightly shouldered; roots white—Shanghai group.
            - (*b*) Leaves toothed with six to ten low, marginal teeth, or entire; roots salmon, or yellow tinged with salmon—Florida group.
    - 2. Leaves without purple stain at the base of the leaf blade (A and B).
        - A. Stems purple—Southern Queen group.
        - B. Stems green (*a* and *b*).
            - (*a*) Stems medium to large in size; roots fusiform, yellow tinged with salmon with light yellow veins—Pumpkin group.
            - (*b*) Stems slender; roots russet-yellow or red, ovoid to fusiform—Jersey group.

In attempting to identify a variety, the group to which it belongs should be determined by means of the key, then the group description should be read, and finally the description of the varieties in the group or section of the group in case it is divided into sections. The group description has been made from the descriptions of the varieties belonging to the group and not from any particular variety.

The eight groups and the varieties belonging to them are:

Ticotea Group.—This group contains only two varieties, Ticotea and Koali Sandwitch, and is not important.

Belmont Group.—This is one of the large groups and is divided into two sections as follows:

Vines long creeping—Belmont section.
Vines very short and bushy—Bunch section.

Belmont (also called Georgia and Dunton's Improved), Eclipse Sugar Yam, Vineless Pumpkin Yam, Georgia (Old Time Yam), Yellow Yam and White Sealy belong to the Belmont Section.

Gros Grandia and Bunch Candy Yam (also called Bunch Yam, Vineless, Prolific and Gold Coin) belong to the Bunch section.

Spanish Group.—The varieties in the Spanish group are separated into three sections as follows:

Roots light yellow to russet yellow—Yellow Spanish section.
Roots light yellow tinged more or less with rose, or deep rose—Bermuda section.
Roots dark red to purple- -Red Spanish section.

In the Yellow Spanish section the roots are light yellow in color, usually very irregular, strongly ribbed and veined, but sometimes fairly smooth and regular; flesh white or yellow. The varieties in this section are Pierson (Arkansas Beauty, California Golden, Early General Grant, Golden Skin and Dutton's Beauty), Yellow Strasburg (Extra Early Golden, Adams), Yellow Spanish (Bronzed Spanish), and Triumph.

The roots of the Bermuda section are light yellow, more or less overlaid with transverse dashes and bands of rose, sometimes washed with rose, or deep rose to purple, usually very irregular, strongly ribbed and veined, but some varieties are quite smooth and regular. The varieties belonging to this section are Red Bermuda (Cuba Yam, Poreland, Yellow Red), Red Brazil or Red Brazilian, Puerto Rico (Golden Beauty, Key West Yam), Key West Yam and Creola.

Roots of the Red Spanish section are more regular and not so constricted; the flesh is white tinged with purple beneath the skin and at the center. This section contains Red Spanish (Black Spanish), Purple Yam or "Nigger Choker" and Dahomey.

Shanghai Group.—Only two varieties belong to this group, Shanghai (Early Golden) and Minnet Yam, and neither is important.

Florida Group.—Three varieties belong to this group, Florida (Arizona Prolific, Providence), General Grant Vineless, and Nancy Hall. The Nancy Hall is one of the important commercial varieties grown in the South. The other two are not important.

Southern Queen Group.—The White Yam and Southern Queen are the only varieties in this group, the latter being one of the best known varieties. It is a good keeper but is of poor quality until late in the storage season. It is known under the following names: Hayman. California Yam, Arkansas Hybrid, Brazilian, Cuban, Common Yam, Johnson's Bahama, Archer's Hybrid, Hamburg, Caroline Lee, Cullman Cream, Catawba White, Catawba Yellow, and Ballinger's Pride.

Pumpkin Group.—This group contains four varieties, Pumpkin Yam, (Early Yellow, Spanish Yam), Norton, Dooley, and White Gilke. Only two of these, Pumpkin Yam and Dooley, are of much importance and these only for home use in the South and on southern markets.

Jersey Group.—The Jersey group is separated into the following sections:

1 { Roots red—Red Jersey
  Roots russet-yellow—2
2 { Stems very short and bushy—Bush
  Stems long—3
3 { Stems medium to large—Big Stem Jersey
  Stems slender—Yellow Jersey

The Red Jersey section contains the Red Jersey (Connelly's Early Red, Early Red Carolina, Red Nansemond, Van Nest Red) and Japan brown, the latter being of no commercial importance.

The stems of the bush section are very short (1 to 2½ feet) rather thick and coarse, with very short internodes and crowded leaves. The varieties in this section are Vineland Bush, Georgia Buck, and Vineless Bunch Nansemond.

The Big Stem Jersey section contains the Phillipili and Big Stem Jersey, sometimes called Florida and Improved Big Stem.

The Yellow Jersey section contains two varieties, Yellow Jersey and Gold Skin. The Yellow Jersey is known under the following names: Nansemond, Early Nansemond, Yellow Nansemond, Early Carolina, Big Leaf, Early Yellow Jersey, McCoy's Sweets, Red Nose, Up Rivers, and Cedarville.

The Big Stem Jersey and the Yellow Jersey are by far the most important varieties grown for northern markets. All of the varieties in the Jersey group are dry and mealy.

Description of Important Varieties.—Since only a few varieties are of much importance the description is limited to them. The Yellow Jersey, Big Stem Jersey, Nancy Hall, and Puerto Rico are the most important commercial varieties and constitute probably 90 per cent of the sweet potatoes grown. Yellow Jersey and Big Stem Jersey are the most important in the northern part of the sweet-potato region and Nancy Hall and Puerto Rico are the most important commercial varieties grown in the South. The Jersey varieties are, however, grown largely in Maryland and Virginia. Other varieties that are of importance in some sections are Triumph, Southern Queen, Dooley, Pumpkin Yam, Red Jersey, Gold Skin, and Belmont or Georgia.

The following descriptions of varieties are taken from the publication prepared by Thompson and Beattie:

YELLOW JERSEY.—Vines small, slender, long, 6 to 12 feet; stems green, hairy, often fasciated; leaves shouldered or entire, hairy only on the upper surface, green; petioles green, hairy; roots dark russet yellow, long or short, fusiform to globular or ovoid in shape (two types known on the market, one long fusiform and another very short), smooth or veined; small to medium in size; season medium; flesh yellow. When baked, very dry and mealy, fairly sweet; texture quite firm.

Big-stem Jersey.—Vines moderately large growing, long, 6 to 12 feet; stems green, hairy; leaves shouldered or entire, hairy above and smooth beneath, green; petiole hairy, green; roots russet yellow in color, smooth and regular, long fusiform in shape, may be veined or smooth, small to large in size, but larger than Yellow Jersey or Red Jersey; season medium to late; flesh yellow. When baked, sweet, dry, and mealy; texture firm.

Nancy Hall.—Vines medium in length, 4 to 8 feet; stems somewhat hairy, green; leaves toothed or entire with four to ten low marginal teeth, hairy on the upper surface and slightly hairy or smooth beneath, green except for a reddish-purple stain at the juncture of the blade and the petiole, the latter slightly hairy, green except at the upper end; roots yellow, tinged more or less with salmon, veined, or smooth and regular, fusiform in shape, medium to large in size; season early; flesh dark yellow, tinged with salmon. When baked, very sweet, moist, and soft in texture; good quality.

Puerto Rico.—Vines medium to long, 5 to 10 feet; stems coarse, internodes short, reddish-purple in color, hairy (especially at the nodes and on young growth); leaves shouldered, large in size, green except for a purple stain at the base of the blade and on the veins, slightly hairy on the upper surface, smooth below; petioles medium long, 5 to 8 inches, reddish purple in color, deeper at the base of the leaf blade, color extends to the veins on the lower side of the leaf and also deeper at the base of the petiole; roots light rose to rose in color, fusiform to globular and irregular in shape, smooth; flesh orange yellow to salmon, but dark yellow when baked; moist, very sweet, good quality.

Triumph.—Vines coarse and vigorous, short, 2 to 4 feet, bushy; leaves shouldered, large and thick, hairy on veins of upper surface, smooth beneath; petioles green, with purple stain at the base of the leaf blade and extending up the veins on the under surface of the leaf; roots medium to long cylindrical in shape light yellow to russet yellow in color; flesh light yellow, but creamy yellow when baked, medium moist to dry, fairly sweet, and firm in texture.

Southern Queen.—Vines large and vigorous, long, 6 to 12 feet; stems dull purple, slightly hairy (especially at the nodes and on new growth); leaves shouldered or entire, slightly hairy above, green; petiole nearly smooth, greenish purple. Roots white or light yellow, sometimes very slightly tinged with pink, smooth and regular, few or no veins, fusiform, globular, or ovoid in shape, medium to large; season medium; flesh light yellow. When baked, sweet, moist, and soft in texture.

Dooley.—Vines long to very long, 10 to 15 feet; stems green, slightly hairy (especially at nodes); leaves shouldered or often entire, green in color, hairy above and smooth beneath; petioles green, slightly hairy; roots large in circumference, short fusiform in shape, yellow to salmon in color; flesh dark orange. When baked, soft and sweet, squashlike.

Pumpkin Yam.—Vines moderately large growing, long, 6 to 12 feet; stems green, hairy; leaves low, shouldered, hairy only on the upper surface, green; petioles green, hairy; roots yellow, tinged with salmon, mostly irregular with prominent light yellow veins, some smooth and regular with few or no veins, fusiform in shape, medium in size; season late; flesh dark orange-yellow. When baked, very sweet, moist, and soft in texture.

Red Jersey.—Vines low and slender in growth, long, 6 to 12 feet; stems green, hairy (especially at the nodes); leaves shouldered, often entire, hairy on the upper surface and smooth beneath, green; petiole green, hairy; roots red in color, fusiform or spindle-shaped, smooth and regular or veined to some extent, small to medium in size; season medium; flesh yellow. When baked, fairly sweet, very dry, and mealy; firm in texture.

Gold Skin.—Vines medium to long, 6 to 10 feet, slender, hairy (especially at nodes), green in color; leaves shouldered or entire (both forms may be found on the same vine), light green, hairy above, slightly hairy beneath; petioles short, slender, hairy, green, except for slight tinge of purple at the base of the leaf blade; roots dark russet yellow, fusiform in shape, smooth and regular; season medium; flesh salmon, but a dark yellow when baked; medium dry and mealy, very sweet; texture firm.

BELMONT.—Vines slender and low, long creeping, 6 to 12 feet; stems light green, hairy; leaves five-parted with basal lobes inclined to shoulder, hairy above and on the veins beneath, light green; petiole hairy, green; roots dark yellow with prominent light yellow veins, fairly smooth and regular, long fusiform in shape, medium in size; season late; flesh golden yellow, but dark yellow when baked, sweet, moist, and soft in texture.

Mutations or Bud Sports.—Many workers have reported the appearance of mutants, or bud sports, in the sweet potato. Harter (1926), Rosa (1926), and Miller (1930) have called attention to mutations in three distinct varieties. Harter (1923) found one plant of the Haiti variety that produced three red roots and three yellow roots as shown in Fig. 57. Plants were grown from all of these roots in 1924; those from red roots produced only red roots and those from yellow roots produced only yellow roots. In 1925 the same procedure was followed with the same results as in 1924. Rosa, working with the Yellow Jersey variety, found one plant that produced two white roots, one root longitudinally striped with white and yellow and several of normal yellow color. One white root and one striped root were kept and plants grown from them the following year. Three plants, obtained from the white part of the striped root, bore only white potatoes. Six plants, grown from the yellow part of the same root, produced only yellow potatoes. Ten plants, obtained from the potato that was white all over, produced only white roots.

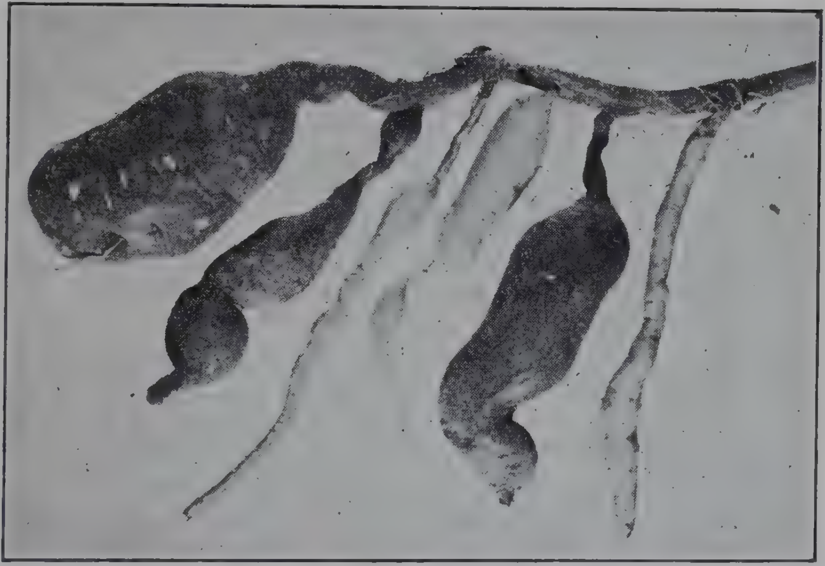

FIG. 57.—Bud sport of Haiti variety of sweet potato. Red and yellow roots produced on same stem. (*Courtesy of U. S. Dept. Agr.*)

Miller (1930) and Miller and Kimbrough (1936) reported several mutations in the Puerto Rico variety. These included roots with (1) white skin, (2) white flesh, (3) white skin and white flesh, (4) white striped, (5) gold skin, (6) purple skin, and (7) vineless or bush. These mutants behaved in a way similar to those described by Harter and by Rosa.

It seems probable that varieties originate as bud sports or mutants. Improvement in the sweet potato might be brought about by taking advantage of these sports.

Improvement.—The sweet-potato seed stock in many regions is badly mixed, due to carelessness in handling and to lack of care in selecting the stock for propagating purposes. Any grower can eliminate all of the potatoes that are not of the variety he desires to grow, merely by sorting the seed roots before bedding them.

In the past, most of the improvement in the sweet potato has been made by clonal selection, since the sweet potato in the United States rarely if ever sets seed under natural conditions. Much improvement has been made by growers and others by hill selection in the field at harvest time. In making hill selection the vigor of the plant, the yield of roots, the color, size and shape of roots, and the incidence of disease should be considered. In ordinary hill selection it is common practice to throw all selected hills together and use them for propagating purposes. This allows no chance to determine the performance of any individual hill. It would be better to plant each hill separately in a row for further study and selection. This is known as the hill-to-row method and makes it possible to discard any hills that do not maintain the standard set. A still better method is the one known as the tuber-unit selection in Irish potatoes. It is based on the fact that potatoes within the hill vary, as do the hills, within the strain. By this method seed is saved only from such units as maintain the desirable characters. These methods do not require annual selection of hills or units from the main field, since after the initial selections are made all further efforts are confined to the seed plots. By means of the root-unit method advantage can be taken of bud sports.

Results of studies by Stout (1926), by Thompson (1925), and especially by Miller (1937 and 1939) show that improvement by hybridization is now possible. Without it there is no possibility of combining desirable characteristics of different strains and varieties. This is now feasible since Miller has worked out a method of growing plants by which it is possible to produce sweet-potato flowers and obtain seed on selfed, crossed, reciprocal-crossed, and inter-crossed flowers of several varieties. Miller (1939) has described in detail the methods he has used so successfully.

Diseases.—Sweet potatoes are subject to diseases in the field and rots in storage. Field diseases may be divided into root and stem diseases and leaf diseases. Stem rot, black rot, foot rot, scurf, and root rot affect the stems and roots, while leaf blight, leaf spot and white rust affect the foliage. The leaf diseases have never been serious enough to require remedial measures.

Storage rots include soft rot, ring rot, black rot, dry rot, Java black rot and charcoal rot. Losses from these diseases are often heavy in storage but may be reduced by proper methods.

Only brief discussions are given of these diseases. The reader desiring more information is referred to the excellent monographic study of Harter and Weimer (1929).

STEM ROT.—This disease, caused by *Fusarium batatatis* and F. *hyperoxysporum*, is found in most of the sweet-potato-growing states. The leaves of affected plants become dull in color, then yellowed between the veins, and somewhat puckered. The young leaves are the first to show signs of the disease. The yellowing of the leaves is followed by wilting of the vine. Diseased stems become blackened inside and this discoloration may extend from 3 to 7 or 8 feet from the base of the plant. The organisms may invade the roots, producing a blackening of the fibrovascular bundles. Sprouts from infected roots are likely to carry the disease although not a large percentage of the slips carry the infection.

The fungus lives over in sweet potatoes in storage and grows from diseased seed into the plants developed from them. It is important, therefore, to use only healthy seed which can be secured by selection at digging time while the potatoes are still attached to the vines. Each hill selected should be tested by splitting the stem, and potatoes should be taken for seed only from plants whose stems are not streaked with black. The seed stock should be stored in a part of the storage house where it will not come in contact with the general stock. Disinfection of the seed with corrosive sublimate, the use of fresh disease-free soil in the plant bed, crop rotation, and the growing of seed from vine cuttings also aid in controlling stem rot. When cuttings are used for growing seed, the vines used should be free from disease and planted on ground that has not produced sweet potatoes for at least 6 years.

Poole (1924) pointed out that crop rotation will not control stem rot since the fungus lives in the soil for many years. Harter and Weimer report an instance where disease-free plants were planted on land that had never produced sweet potatoes and 40 per cent of the plants developed stem rot. This infestation of the soil may be accounted for by the carrying of the spores from adjoining fields by wind and by drainage water.

Dissemination from one locality to another is by the usual channels of trade in seed potatoes or in plants.

Black Rot.—This disease is caused by the fungus *Ceratostomella fimbriata*, which attacks any underground portion of plant. It causes heavy losses, both in the field and in storage. Poole (1922) reports losses as high as 75 per cent in storage. On the potato, the rot occurs as moist, circular, dark-brown to black spots. These spots enlarge and under conditions favorable to growth of the fungus, may cover nearly the whole potato. During the early stages of black rot in the seedbed, the foliage is yellowed and sickly in appearance. Black cankers may develop on the stem below the surface of the soil. In severe cases of infection all the sprouts may be killed before they get through the soil.

The fungus probably lives over in the soil and in infected tubers in storage. There is evidence that the fungus spreads in the storage house.

The control measures mentioned for stem rot should be applied to black rot. All potatoes that show disease should be discarded at harvest time and careful selection made at bedding time so that no roots infected with black rot are used for growing plants. Development of black rot can be kept in check in the storage house by carefully controlling the temperature and the humidity of the air.

Foot Rot.—This disease is caused by the fungus *Plenodomus destruens*. In the seedbed it causes a stunting and, in severe infestation, the death of the plants. This disease appears first as small brown to black spots on the stem of the plant near the ground. Its growth is very slow at first but eventually it girdles the plant. Soon after this, the plant wilts and round, black specks, just visible to the naked eye, appear in the diseased areas. These are the fruiting bodies. The organism may grow from an infected stem on to the roots and cause a brown, rather firm rot of the potato. Later fruiting bodies standing close together develop on the surface in the form of pimplelike protuberances. This disease is not so widely distributed as stem rot and black rot.

Seed selection, use of clean plant beds, and crop rotation are the control measures recommended. The disease is carried from the field to the storage house on the potatoes and back to the field on the slips.

Scurf.—This disease, also known as soil stain, is caused by the fungus *Monilochaetes infuscans*. It appears as a brown discoloration on the surface of underground parts of the plant. The fungus does not break the skin and may be easily scraped off by the fingernail. It is worse on heavy soils and on soils containing a large quantity of organic matter. It is also worse during a wet season and on low ground. Loss by this disease is not heavy compared to some of the others.

Treating the seed with corrosive sublimate solution and use of fresh soil for the seedbed are control measures suggested.

Poole (1922) experimented with various fungicides and found that sulphur aids in the control of the disease. He suggested 300 to 400 pounds of inoculated sulphur to the acre, applied broadcast on the land before the potatoes are to be planted. It should be borne in mind, however, that the sulphur increases acidity and this might be objectionable, particularly for succeeding crops or on soil that is already acid.

TEXAS ROOT ROT.—This disease is well known on cotton and alfalfa and is caused by *Phymatotrichum omnivorum* (Shear) Duggar; (*Ozonium omnivorum*, Shear). It occurs only in Texas, Oklahoma, New Mexico, Arizona, and California, so far as is known. The organism gains access to the plant on the underground parts and spreads in both directions. It may enter the potato or cause spots on the surface. In either case a brown rot is produced resulting in the complete destruction of the potato. The organism lives over winter in the soil on dead vegetable matter or, in the far South, probably on winter crops. It is killed by hard freezing and is therefore restricted to the southern states.

This disease is difficult to control because it grows on a great variety of plants. Deep, clean cultivation, crop rotation, and selection of disease-free seed are recommended.

LEAF BLIGHT.—This disease is caused by *Phyllosticta batatas*. It appears on the upper side of the leaf as roundish or angular spots ⅛ to ½ inch in diameter and separated from the healthy tissue by a dark line. Inside this line is a strip of brownish tissue which has lost most of its green color. Inside this ring is a circular area, much lighter in color, in which a number of black bodies containing spores are found. So far as is known this fungus does not attack other plants; neither does it occur on other parts of the plant.

Leaf blight occurs practically every year in the southern states but is less common in New Jersey, Delaware, Maryland, Kansas, Iowa, and Illinois. It is seldom serious enough to require remedial measures.

LEAF SPOT.—The leaf-spot fungus, *Septoria bataticola*, produces spots on the leaves similar to leaf blight. The spots, scattered indiscriminately over the foliage, are white surrounded with a brown border. Within these white areas one or more black specks may be found. These specks contain spores which are carried by insects and other agencies to other leaves. The disease probably lives over winter on the dead leaves in the field.

It is not serious enough anywhere to require remedial measures.

WHITE RUST.—(*Albugo ipomoeae-panduranae*).—The first symptom of this disease is a loss of the green color in spots on the underside of the leaf. Later these spots become brown and covered with whitish, viscid growth which is finally more or less powdery. This disease causes no great amount of harm, although it is widely distributed and occurs on a number of other plants, including wild morning-glories.

Soft Rot.—Soft rot, one of the most destructive diseases in the storage house, is caused by *Rhizopus nigricans*. The decay begins at one end of the potato and grows rapidly, under favorable temperatures and humidity. The potatoes are first rendered soft, watery, and stringy, but later they become firm, hard, and brittle. One soft-rot potato may communicate the disease to all the potatoes in contact with it. The spores of the black mold produced on the surface may be carried by flies to other potatoes or may be communicated to them by handling.

Lauritzen and Harter (1926) have shown that infection takes place almost exclusively through fresh wounds, so that careful handling is important. At a temperature of 23°C. the optimum relative humidities for the infection of roots by the organism ranges from 75 to 84 per cent. Infection decreases rapidly as the humidity is raised or lowered. Since the resistance to infection is in the surface layers, it is believed to be related to cork formation and Harter and Weimer (1921) found that cork formation occurs more rapidly at high than at low humidities.

Ring Rot.—This disease is caused by the same mold (common bread mold) as the soft rot. Ring rot differs from soft rot in that the decay begins at a point between the two ends instead of at the ends. From the point of infection the decay forms a ring around the potato.

Dry Rot (*Diaporthe batatatis*).—Dry rot is a disease of sweet potatoes in storage. It generally begins at the end of the potato, producing a firm brown rot. It grows slowly, the potato finally becoming dry, hard, and mummified. Small domelike protuberances just visible to the naked eye finally cover the entire surface. If the skin is scraped slightly, the tissue beneath presents a coal-black appearance.

Dry rot is widely distributed, but is not one of the more serious storage troubles.

Java Black Rot (*Diplodia tubericola*).—This disease is strictly a storage trouble. It is similar in appearance to dry rot and is widely distributed, but is most prevalent in the South. The disease begins at the end and grows very slowly, requiring under normal storage conditions from 4 to 8 weeks to destroy the potato.

Charcoal Rot (*Sclerotium bataticola*).—This storage rot is of less economic importance than most of the others. It differs from the others of a similar appearance by the production by the fungus of minute spherical resting bodies throughout the potato, rarely on the surface. These bodies are coal black.

Control of Storage Rots.—Elimination of the field diseases which are also troublesome is one of the important control measures.

Careful handling to prevent any breaking of the skin or bruising of the surface should be practiced since many of the diseases gain entrance through injured tissues. Thorough curing and maintaining good storage conditions will materially aid in controlling storage rots.

Insects.—The sweet potato is attacked by relatively few insects, and except for the sweet-potato weevil, the injury done is usually small. Among the insects that attack the sweet potato are the weevil, the sweet-potato flea beetle, striped beetle, sweet-potato plume moth, sweet-potato white fly, and the sweet-potato leaf folder. Berger (1918) mentions termites or white ants as burrowing into sweet potatoes and causing injury in Florida. Only the sweet-potato weevil is considered of sufficient importance to justify discussion here.

SWEET-POTATO WEEVIL (*Cylas formicaris* Fab.).—The adult is a slender-snout beetle about ¼ inch long. It is of Asiatic origin and was known in Louisiana as early as 1875 and in Florida in 1878. It was not given much consideration until about 1910. The weevil is now widely distributed in Florida, Louisiana, and Texas, and is found in parts of Georgia, Oklahoma, Alabama, and Mississippi.

This insect is restricted for food to the sweet potato and closely related plants of the morning-glory family. The goatsfoot morning-glory (*Ipomoea prescapre*), which grows in sandy soils along tropical seashores, is considered a natural food plant. Chittenden (1919) states that the weevil injures the sweet potato by feeding on the leaves, vines, and roots. The female lays eggs in the vines near the ground and in the roots in the field, and continues to breed in the roots in storage. The larvae tunnel through the vines to the roots, the vines die, and the roots frequently become so badly riddled and filled with bitter excreta that hogs will not eat them. Losses of 25 to 50 per cent are common, and in severe infestations, there may be total loss.

Where the weevil is well established, infestation takes place through overwintered weevils. They may live over in stored potatoes and in roots left in the ground. Outbreaks of the weevil in a new locality, in nearly all cases, may be traced to the transportation of propagating material.

Control measures for the weevil in regions where it is established consist in cleaning up sweet-potato fields, storage houses, storage banks, and plant beds, and in using plants known to be free from the insect. Graf and Boyden (1921) suggested the following rules for farmers:

1. The old fields should be thoroughly cleaned at harvest time, the vines being fed to stock or burned, and the fields "hogged over."
2. The potatoes should be banked as far as possible from the old field and from the site selected for the field the next year.
3. All potatoes on the farm should be disposed of early.

4. No potatoes or plants from the old crop should be used on the farm and no draw-bed should be planted.

5. Old potato banks should be cleaned as soon as empty.

6. Only draws (plants) from sources known to be free from the weevil should be used.

All regions known to be infested with the sweet-potato weevil should be strictly quarantined to prevent the movement into uninfested territory of any material likely to carry the insect. Most of the southern states have laws prohibiting the shipment of sweet potatoes, sweet-potato plants, and morning-glory plants or parts of plants from infested to uninfested areas. Such laws, strictly enforced, delay, if they do not prevent, the spread of the weevil.

Harvesting.—When grown for the early market, sweet potatoes may be harvested as soon as the tubers reach marketable size, regardless of the stage of maturity. The main crop, which is intended for storage, should be well matured before digging. When the potatoes are mature a broken or cut surface dries on exposure to the air, while an immature one remains moist and turns dark in color. However, in regions where early frosts occur the potatoes should be dug about the time of the first hard frost regardless of their stage of maturity. If frost kills the vines, the potatoes should be dug immediately as decay sets in on the dead vines and may pass down to the roots. In case it is impossible to dig immediately, the vines should be cut away and loose soil thrown over the rows for protection from the cold.

The digging implement should be one that does not cut or bruise the roots. One of the best types is a plow with rolling colters on the beam to cut the vines and with rods attached to the small moldboard to free the roots from the soil. A large turnplow or a "middle buster" may be used. The machine digger used for Irish potatoes should not be used in digging sweet potatoes as the roots would be bruised in being carried over the rods. After the potatoes are plowed out, they are scratched out by hand and left on the ground long enough to dry. The digging should be done, if possible, when the weather is bright and the soil dry.

Sweet potatoes should be graded somewhat as they are gathered so as to eliminate extra handling. Where they are marketed as soon as harvested it is common practice to grade and pack in the field. If the potatoes are to be stored it is a good plan to go over the rows and pick up the sound marketable ones in one basket, then gather the seed stock in another, and put the injured ones in still another. This eliminates extra handling and thereby reduces the loss by decay, since in any handling there is some bruising, which hastens decay. The baskets or other containers used should be loaded on a wagon with springs and hauled direct to the storage house. The potatoes should never be dumped into the wagon bed.

The importance of careful handling is illustrated in experimental results reported by Thompson and Beattie (1922). Three varieties of sweet potatoes, Big Stem Jersey, Nancy Hall, and Southern Queen were used. At harvest time all of the cut and bruised roots were picked up and stored separately. The average shrinkage of these in storage was 28.13 per cent as compared to 13.83 per cent for the uninjured potatoes of the same varieties stored under identical conditions. The loss by decay for the storage period of 164 days was 13.79 per cent for those that were injured in harvesting and 0.75 for the uninjured ones. The Southern Queen lost the least by shrinkage and decay. The loss in value was even greater than the percentage figures for shrinkage and decay indicate since injured potatoes are unattractive in appearance and the injured parts must be cut away in preparation for the table.

Grading.—Sweet potatoes should be carefully graded for market whether they are to be sold at harvest time or after storage. Well-graded potatoes of inferior quality frequently sell at a higher price than poorly graded or ungraded stock of good quality. In grading, all characteristics that affect the market quality should be considered. These include size, shape, color, and blemishes, or injury of any kind.

When the potatoes are sold at harvest time they may be graded in the field or in a packing house; the latter is to be preferred. Grading at the packing house or storage house is commonly done on portable tables, which consist of frames of a suitable height with burlap fastened over the tops. As the potatoes are delivered, they are dumped on to the tables. The graders sort out and pack those that conform to the grade requirements, the remainder being kept at home.

After sweet potatoes have been stored for a considerable period, they should be regraded before being sent to market no matter how carefully they were graded before. If they were carefully graded at harvest time and little or no rot has developed in storage, the regrading may be done by partly emptying the container and picking out damaged or diseased specimens. Better grading can be done, however, by dumping all the potatoes from the containers and repacking. The graders and packers should wear gloves to prevent injuring the surface of the potatoes with the finger nails and all handling should be carefully done to prevent bruising.

Standards have been promulgated by the U. S. Department of Agriculture for three grades. These were developed for all sections of the country and for all varieties so that they permit considerable variation. It is possible, therefore, to comply with the minimum requirements of these grades and have a product that lacks uniformity in size and shape. Shippers should not be satisfied with meeting the minimum requirements.

Packing.—Sweet potatoes are packed in various types of containers including hampers, round stave baskets, crates, and boxes. It is important that the container be strong and rigid to eliminate breakage and to prevent bruising of the potatoes.

Sweet potatoes should be packed in clean, neat, substantial containers that show off the product to good advantage when opened for inspection. The container should be well filled when packed. Unless it is more than level full when packed the constant jarring and jolting of a long freight haul cause it to reach its destination only partly full. Loose packing allows the potatoes to shift about resulting in bruising and this is often followed by decay. The shape of the sweet potato does not lend itself to a jumble pack. To carry properly each potato should be placed by hand and each layer so arranged that the vacant spaces are filled. With any type of container it is desirable to face the top layer, but the potatoes in this layer should be representative of the contents of the container.

The package should be labeled to show the grade of the product and the quantity. An amendment to the federal food and drugs act provides that goods in package form shall be deemed misbranded unless the quantity of the contents is plainly and conspicuously marked on the outside of the package in terms of weight, measure, or numerical count. Sweet potatoes shipped in interstate or foreign commerce, or offered for sale in the District of Columbia or territories of the United States, are subject to this act if put up in package form.

Storage.—The improvement in the methods of storage during recent years has done more to increase the value of this crop than anything else. With good storage it is no longer necessary to put the potatoes on the market in the fall when the supply is greater than the demand. Nor is it necessary to lose 30 per cent of them by decay, since by care in handling and by storing in the proper type of storage house the loss by decay should be less than 5 per cent.

To keep sweet potatoes in good condition they must be (1) well matured before digging, (2) carefully handled, (3) well dried or cured after being put in the storage house, and (4) kept at a uniform and relatively high temperature and low humidity after they are cured.

The stage of maturity at which the potatoes should be dug is discussed under "Harvesting."

Careful handling is important since the sweet potato is very easily bruised and organisms causing decay often enter the injured surface. Even if decay does not set in, the bruised areas become discolored and hard, thus injuring the appearance and reducing the quality. The sweet potato will not stand so much rough handling as the Irish potato. In fact very few products are more easily injured than the sweet potato and it should be given as careful handling as apples and oranges.

Curing.—Sweet potatoes are "cured" by maintaining a high temperature, 80° to 95°F., with good ventilation, for a period of 10 days to 3 weeks. The length of time depends on the weather conditions and, to some extent, on the variety. During cloudy or rainy weather, when the humidity is high, a longer period is required than when the humidity is low. Ventilation is necessary to drive off the moisture-laden air. The curing is necessary to reduce the moisture content of the sweet potatoes and thus prevent the development of decay. During the curing process the potatoes should lose 6 to 8 per cent of their original weight. The doors and windows of the storage house may be closed at night and during cloudy and rainy days, but some of the ventilators

Table L.—Relation of Temperature during Storage to the Keeping Quality of Sweet Potatoes

(Shrinkage and decay averages of three standard varieties in storage-house tests during two seasons)

Variety	Temperature, deg. F.	Weight* at harvest time, lb.	Loss in weight during curing, per cent	Loss in weight at end of—						Loss due to decay 164 days	
				51 days, per cent	82 days, per cent	111 days, per cent	141 days, per cent	164 days			
								Lb.	Per cent	Lb.	Per cent
Big Stem Jersey.......	50 to 55	142.56	6.59	8.02	9.42	10.88	12.09	19.31	13.54	1.81	1.27
Nancy Hall...........	50 to 55	140.00	7.14	8.46	9.69	11.03	12.12	18.44	13.10	0.84	0.60
Southern Queen.......	50 to 55	153.09	7.83	9.12	10.49	12.00	13.21	22.50	14.69	0.59	0.38
Total for three varieties.............	....	435.67	....	.....	.....	.....	.....	60.25	.....	3.25	
Average for three varieties..........	....	......	7.23	8.55	9.88	11.33	12.49	.....	13.83	.....	0.75
Big Stem Jersey.......	55 to 60	144.16	7.74	9.02	10.82	12.59	14.24	22.50	15.61	1.69	1.17
Nancy Hall...........	55 to 60	144.47	8.50	9.73	11.12	12.74	14.30	22.31	15.45	0.72	0.49
Southern Queen.......	55 to 60	151.72	8.71	9.68	11.53	12.09	14.03	22.44	14.79	0.56	0.37
Total for three varieties.............	....	440.34	....	.....	.....	.....	.....	67.25	.....	2.97	
Average for three varieties..........	....	......	8.32	9.48	11.16	12.47	14.18	.....	15.27	....	0.67
Big Stem Jersey.......	60 to 65	139.94	7.98	9.60	12.10	13.75	15.46	23.62	16.85	3.31	2.36
Nancy Hall...........	60 to 65	143.16	9.17	11.05	13.18	14.69	15.89	24.12	16.85	0.78	0.54
Southern Queen.......	60 to 65	150.53	6.73	8.24	10.40	11.73	12.81	20.34	13.51		
Total for three varieties.............	....	433.62	....	.....	.....	.....	.....	68.09	.....	4.09	
Average for three varieties..........	....	......	7.93	9.61	11.87	13.22	14.68	.....	15.70	....	0.96

* Weight means the weight of potatoes stored per year (total weight divided by 2).

should be left open throughout the curing period. The air inside should be kept at a higher temperature than the outside air. This will prevent moisture from being deposited on the walls and other interior portions of the house. When the potatoes are thoroughly cured the temperature should be reduced gradually to about 55°F.

During the curing period, the relative humidity should be kept below 70 per cent so that rapid drying may take place. After the curing period the humidity should be maintained between 75 and 85 per cent according to Kelley (1929). If the humidity is too high, rot is likely to develop, and if too low, excessive shrinkage results.

STORAGE TEMPERATURE.—Most authorities recommend a temperature of 50° to 55°F. after the curing period and this has proved very satisfactory in practice. Experiments by Thompson and Beattie (1922) show that the shrinkage increased as the temperature was raised. Table L gives the loss in weight at various intervals during storage and loss due to decay for the period of 164 days.

Examination of Table L will show that the average percentage of shrinkage for the three varieties increased with a rise in temperature. This was true for every period after curing. It will also be noticed that over half of the shrinkage occurred during the curing period. After the curing period the shrinkage continues, but the rate is rather slow, averaging less than 1½ per cent a month under the three sets of temperatures. The average total shrinkage, even at the highest temperature, was not excessive for such a long period and with potatoes stored in crates. The average storage period is not over 3 or 3½ months. At the end of 111 days, the average shrinkage in these experiments was 11.33, 12.47, and 13.22 per cent. A shrinkage of at least 10 per cent for a storage period of 5 months is necessary and half of this should occur during the curing period. The difference in percentage of decay is not significant as the potatoes in the three storage rooms kept in almost perfect condition.

When the temperature in the storage house goes below 48°F. a fire should be started, or the house opened during the middle of the day when the temperature on the outside is higher than on the inside and the humidity of the outside air is not too high. When the temperature goes above 60°F., it is desirable to open the house in the cool of the day if the weather conditions are favorable.

COMPARISON OF BINS AND CRATES.—It is often asserted that crates, baskets, and other small containers are better than bins, because when decay sets in it is likely to be confined to the container, but in bins the decay may spread throughout the bulk of the potatoes. The extra handling required when bin storage is used increases the chances for bruising the potatoes. Ordinarily, there is considerable bruising in dumping the potatoes into the bins.

Experiments conducted for 2 years by Thompson and Beattie show that shrinkage was a little greater in crates than in bins, but decay was slightly greater in the latter. The average shrinkage for three standard varieties was 12.88 per cent in bins and 14.02 per cent in crates, while the decay was 1 and 0.57 per cent respectively. The conditions were so nearly ideal that the loss was practically nothing. Under less favorable conditions the difference in percentage of decay would probably have been greater.

Sorting versus Not Sorting.—It has been quite generally believed that when sweet potatoes begin to decay in storage they should be sorted to pick out the diseased ones. Experiments reported by Thompson and Beattie indicate that it is inadvisable to disturb the potatoes even to pick out those that are decaying. In seven tests, including three varieties, covering 4 years the average loss by decay was 2.63 per cent for those sorted and 1.21 per cent for those not sorted. In six lots out of the seven, the sorted potatoes had the larger percentage of decay. The sorting was carefully done about once a month during the storage period which averaged 134 days. Under less careful handling there would undoubtedly have been more decay in both sorted and unsorted lots, but especially in the former. The probable explanation of the greater amount of decay in the sorted lots is that slight bruising resulted from handling and that the sorting increased the chance of spreading disease from decayed to sound potatoes. One decayed potato left undisturbed might be in contact with several sound ones, all of which would eventually become diseased, but it would require considerable time for all of them to decay completely. When sorted, each of the potatoes which had become infected with disease might be placed in contact with several uninfected ones, thereby, spreading the disease to them.

Since sorting apparently increases disease injury and requires considerable labor, it seems inadvisable to sort them until they are to be placed on the market. When decay is serious, the potatoes should be sorted and disposed of immediately.

Changes during Storage.—Attention has been called to the loss in weight of sweet potatoes in storage. Table L shows the percentage loss in weight at various times during storage. It has been assumed that the decrease in weight is accounted for by the loss of moisture, but this does not account for all of it. The percentage of water in sweet potatoes does not vary to any great extent during storage, although it is well known that moisture is lost.

Other changes that take place in the sweet potato during storage are transformations of carbohydrates, notably a decrease in starch and an increase of sugar. Harrington (1895) found that there was an increase in sugar up to Mar. 6, beyond which his experiments were not continued.

Shiver (1901) found that during the time of his experiments (up to April 17) there was a gradual decrease of starch and an increase of cane sugar, while the invert sugar showed but slight fluctuations. Hasselbring and Hawkins (1915) show the changes in two varieties, Big Stem Jersey and Southern Queen, from harvest Oct. 20, 1911 to June 1, 1912. These potatoes were held at temperatures ranging from 11.7° to 21°C. after the curing period, but mainly between 11.7° to 16.7°C. Table LI shows the percentage of water, starch, cane sugar, reducing sugar as glucose, total sugar as glucose, and total carbohydrates as glucose. The percentages of carbohydrates were all referred to the original moisture content of the potatoes.

Table LI.—Carbohydrate Transformations in Sweet Potatoes during Storage

(Adapted from Hasselbring and Hawkins)

Big Stem Jerseys

Date	Water, per cent	Starch, per cent	Cane sugar, per cent	Reducing sugar as glucose, per cent	Total sugar as glucose, per cent	Total carbohydrates as glucose, per cent
Oct. 20	73.50	19.07	1.90	0.90	2.90	24.09
Nov. 8	72.99	16.94	3.51	1.32	5.02	23.85
Dec. 6	71.89	16.42	3.94	1.40	5.55	23.79
Jan. 4	72.06	16.02	4.39	1.28	5.90	23.70
Feb. 1	72.18	14.11	6.06	1.67	8.04	23.71
Mar. 1	71.97	13.09	6.96	1.44	8.76	23.31
Mar. 20	73.02	13.44	6.40	1.10	7.84	22.77
Mar. 26	72.49	14.47	5.61	0.87	6.77	22.85
Apr. 16	72.87	14.20	6.03	0.90	7.24	23.02
June 1	72.45	14.62	5.85	0.87	7.02	23.27
Southern Queen						
Oct. 23	71.69	22.09	1.19	0.39	1.64	26.18
Nov. 10	68.41	19.87	2.97	0.77	3.89	25.96
Dec. 7	67.69	19.30	3.50	0.72	4.41	25.85
Jan. 11	67.51	19.75	3.53	0.75	4.46	26.41
Feb. 3	68.02	19.22	3.95	0.60	4.75	26.11
Feb. 28	68.00	18.99	4.05	0.53	4.80	25.90
Apr. 8	66.71	20.35	2.93	0.52	3.61	26.22
May 4	69.21	19.78	3.39	0.51	4.07	26.05
June 4	68.15	20.15	2.80	0.55	3.50	25.89

The data in Table LI show that the moisture content of the roots remains fairly constant. The loss of moisture is masked by the loss in sugars in respiration and by the water formed in the same process. Kimbrough (1929) has shown that most of the loss in weight in sweet potatoes during storage is due to the loss of water.

During growth the sweet potato root has a very low sugar content, the reserve materials being deposited almost wholly as starch. After harvest there occurs a rapid change of starch to sugar. The initial change seems to be due to internal causes and is largely independent of external conditions. In the experiments, conducted by Hasselbring and Hawkins, the transformation took place at temperatures as low as 4°C. and as high as 30°C. At the lower temperature there was a rapid disappearance of starch and an accompanying increase of cane sugar, but the potatoes rotted before equilibrium was reached. During the curing period when the temperature averaged about 30°C. sugars accumulated in excess of the quantity used in respiration. Toward the end of the storage period there is a gradual loss in sugars and an increase in starch.

The changes in sweet potatoes during storage, especially the decrease in starch and the increase in sugar, account for the difference in taste between freshly dug potatoes and those of the same variety that have been stored for a while. Freshly dug sweet potatoes are dry when cooked, while stored potatoes are moist. The so-called dry-fleshed varieties have a lower sugar content than the moist-fleshed varieties. Analyses by Harrington (1895), March 6, 1894, of a number of varieties show a variation of total sugar from 7.55 per cent in the Delaware (probably a Jersey) to 19.71 per cent in the Early Bunch Yam, a moist-fleshed variety. Nansemond (Yellow Jersey), a dry-fleshed potato, contained 8 per cent total sugar. All of the so-called moist-fleshed varieties are high in sugar. The moisture content of the two types is practically the same.

Culpepper and Magoon (1926) have shown that not only do marked changes take place during curing and storage, but that further alterations take place during cooking.

> The chemical changes taking place are evidenced by a transformation of part of the starch to dextrin and sucrose, thus altering the starch-moisture ratio, and during cooking a splitting of a portion of the starch to maltose. These changes are responsible for the altered physical consistency of the canned product and its increase in sweetness. The ratio of starch to moisture determines the consistency and the chief factor causing the difference in sweetness is the amount of sucrose formed.

Storage Houses.—Sweet-potato storage houses should be well built, well insulated, and provided with adequate heating and ventilating systems. It is important to have them tight so that there is little or no leakage of air around the openings or through the walls, floor, and roof. Good insulation helps in maintaining a fairly uniform temperature regardless of the fluctuations outside.

Sweet-potato storage houses may be built of any of the ordinary building materials, but most small houses, and many of the larger ones, are built of wood. Wood is a fairly good insulator and may be used to advantage to insulate walls and roof of a sweet-potato storage house if there is a sufficient number of layers with building paper between to prevent the passage of air through the cracks. Insulating boards are more efficient than wood of equal thickness and may be used. Where wood is used for the walls it is not desirable to fill the space between the layers of boards with sawdust, shavings, or any similar material for these will absorb moisture and when once wet will not dry out. This will result in keeping the atmosphere damp and rotting the wood. Furthermore, these materials settle and leave open spaces in the wall. Other material, such as brick, hollow tile, and concrete blocks are used and are satisfactory if the building is properly constructed.

A good ventilation system should be provided so that the air can be changed quickly when desired; this is very important during the curing period. Ventilation is provided by means of doors, windows, and special openings through the floor or through the walls near the floor and through the roof. All doors and windows and ventilators should be made to close tightly. Double doors are desirable and shutters should be provided for the windows, preferably on the inside. Windows should be as few as will provide sufficient light for the workmen. Excessive light favors sprouting and large glass areas permit rapid loss of heat.

Large storage houses should be divided into rooms of such size that one room may be filled in a week or less. If the rooms are too large it is difficult, if not impossible, to cure the potatoes evenly. It is desirable to store the seed stock in a separate room so that it may remain undisturbed until planting time. Each room should have separate heat control.

Heating the Storage House.—The type of heating apparatus used depends to a considerable extent upon the size of the house. For a small house, a small sheet-iron, wood-burning stove or a small coal stove may be used. Oil stoves are used for small houses in some sections of the South, but these are not entirely satisfactory. For large houses, hot-water or steam heat is preferable since the heat can be more evenly distributed than with stoves, or even with hot-air furnaces. Some houses are heated by hot-air furnaces with the air pipes placed under the bins. Heating by electricity has been reported by Schaller and Drain (1938) as very satisfactory in three storage houses in Tennessee, one in Georgia, and one in Mississippi. They state that electricity provides increase of storage capacity, automatic temperature control, and even distribution of heat and reduces labor requirement, storage losses, and danger of fire. The electric current consumed averaged about 1 kilowatt-hour per bushel, including curing in October and storage until April; the operating cost varied from 2 to 6 cents per bushel for the entire period, depending on cost of current, type of construction, and whether or not the house was filled to capacity.

Storage Pits.—A large part of the sweet potato crop grown in the South is stored in outdoor pits or banks although the percentage so stored is decreasing each year. The average loss by decay by this method of storage is at least 30 per cent, but this can be materially reduced by using care in handling the potatoes and in constructing the pit or bank. Experiments to compare house and pit storage, were conducted by the U. S. Department of Agriculture for 3 years in the South. Records covering ten tests on 984,000 bushels of sweet potatoes stored in houses showed only 1.20 per cent loss due to decay, while the decay averaged 14.33 per cent in the same number of tests on 204,300 bushels stored in pits. In these experiments the potatoes were handled carefully and the pits were much better than the average. In addition to the loss by decay in pits and banks, the quality of the potatoes is very inferior due to lack of proper curing, and they decay rapidly when removed. It is very inconvenient to get the potatoes out of a pit or bank when needed, especially during cold or rainy weather.

CHAPTER XXIV

BEANS AND PEAS

Broad Bean
Kidney Bean
Scarlet Runner or Multiflora Bean
Lima Bean
Tepary Bean
Soybean
Cowpea
Peas

While beans and peas belong to the same family (*Leguminoseae*), their cultural requirements have few points in common. All of the beans grown in America, except the broad bean, are warm-season plants, while the pea is relatively hardy and grows best under cool conditions. The beans and peas, in common with other legumes, are capable of utilizing atmospheric nitrogen by the aid of bacteria found in the nodules on the roots of the plants.

BEANS

The term "bean," as used here, includes the following species representing six genera: (1) broad bean or Windsor bean (*Vicia faba*); (2) kidney bean (*Phaseolus vulgaris*); (3) Metcalfe bean (*P. Metcalfei*); (4) tepary bean (*P. acutifolius*, Gray, var. *latifolius*, Freeman); (5) scarlet runner or multiflora bean (*P. coccineus*, also called *P. multiflorus*); (6) sieva bean (*P. lunatus*); (7) Lima bean (*P. limensis* Macf.); (8) urd bean (*P. mungo*); (9) mung bean (*P. aureus*); (10) adzuki bean (*P. angularis*); (11) rice bean (*P. calcaratus*); (12) moth bean (*P. aconitifolius*); (13) asparagus bean or yard-long bean (*Vigna sesquipedalis*); (14) hyacinth bean (*Dolichos lablab*); (15) velvet bean or Florida velvet bean (*Stizolobium Deeringianum*); (16) soybean (*Glycine Max* or *Soja Max*); and (17) cowpea (*Vigna sinensis*).

Soybeans, cowpeas, and velvet beans are used mainly as feed for livestock and as soil-improving crops in the United States, although the cowpea is used to a considerable extent as food in the South. In China the soybean is a very important article of food. The hyacinth bean is grown mainly as an ornamental plant in the United States. The urd, mung, and adzuki beans are little known in America and the tepary is grown mainly in the Southwest.

BROAD BEAN

The broad bean is a hardy plant, native of Europe and Asia. It is one of the most ancient of the cultivated esculents, having been grown by the ancient Greeks, Romans, Hebrews, and Egyptians. It is said to have been introduced into China about 2822 B.C. This bean is seldom grown in America since the summers are too hot and the winters of the North are so cold that it cannot be planted in the autumn and carried over. In some sections of the South and of the Pacific coast, the seed may be planted in the autumn or during the winter for a spring crop, but other types of beans are so easily grown that the extra effort necessary to produce the broad bean does not seem to be justified. In southern Europe, the seed is often planted in the fall and the young plants are protected during the winter. Broad beans are used either as green or dry beans, and as feed for horses.

The broad bean is grown to some extent in California, where it is planted in February and March in the warmer sections and later in the cooler regions, near San Francisco. It is grown to some extent for home use by Italians and other people of foreign extraction, but it is not of much importance as a crop. The broad bean is considered inferior in quality to other types of beans grown in the United States and, for this reason, it has not gained much of a foothold.

COMMON OR KIDNEY BEAN

The kidney bean (*P. vulgaris*) is the most important species of bean grown in the United States and in common usage the term "bean" applies to types and varieties belonging to this species. This crop is grown by a large percentage of home gardeners and, as a market crop, it is produced for market as snap beans, green-shell beans, and dry beans. It is also grown on a large scale for canning.

Statistics of Production.—During the 20-year period, 1918 to 1937, the acreage of land devoted to the production of snap beans for market in the fresh condition increased over fivefold. The yield per acre decreased markedly during this period as is shown by the figures given in Table LII. The explanation for the decrease in average yield per acre is not clear, but it seems probable that expansion has taken place in areas not well suited to bean production. The spread of bean pests, especially

TABLE LII.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND FARM VALUE OF SNAP BEANS GROWN FOR MARKET BY 5-YEAR PERIODS 1918 TO 1937

Years	Acres	Yield, bu. per acre	Production, bu. (000 omitted)	Price per bushel	Farm value (000 omitted)
1918–1922	28,106	132	3,715	$1.74	$ 6,463
1923–1927	64,266	93	5,982	1.90	11,389
1928–1932	110,600	88	9,726	1.34	13,013
1933–1937	160,808	80	12,859	1.02	13,102

the Mexican bean beetle, might be a factor. The price received for snap beans also decreased in the last 10 years. The marked increase in production and the general economic conditions prevailing since 1929 probably account largely for the decrease in price.

Snap-bean production for manufacture also increased in the period from 1918 to 1937, but during the period 1928 to 1932 the acreage was higher than in the period 1933 to 1937 as is shown in Table LIII.

TABLE LIII.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF SNAP BEANS GROWN FOR MANUFACTURE BY 5-YEAR PERIODS 1918 TO 1937

Years	Acres	Yield per acre, tons	Production, tons	Price per ton	Value (000 omitted)
1918–1922	12,246	2.4	29,280	$58.33	$1,708
1923–1927	28,862	1.8	50,920	63.24	3,220
1928–1932	54,710	1.34	73,100	57.54	4,206
1933–1937	49,214	1.58	77,980	43.70	3,408

The dry-bean industry is of much greater importance than the green- or snap-bean industry. The average annual acreage for the period 1928 to 1932 was estimated at 1,806,000 acres, producing 12,181,000 bags of 100 pounds each. In 1937 the estimated cash income for dry, edible beans was $47,437,000. The estimated acreage, yield per acre, production, and cash income from dry beans grown in the important producing states are given in Table LIV.

TABLE LIV.—ESTIMATED ACREAGE, YIELD, PRODUCTION, AND CASH INCOME FROM DRY EDIBLE BEANS IN 1937
(*Crops and Markets*, December 1937)

State	Acres	Yield, lb. per acre	Production in 100-lb. bags (000 omitted)	Cash income (000 omitted)
Michigan....................	485,000	940	4,559	$12,600
California....................	386,000	1,391	5,369	17,700
Colorado....................	244,000	320	781	3,125
New Mexico..................	175,000	350	612	1,275
New York....................	158,000	800	1,264	4,200
Idaho.......................	140,000	1,380	1,932	4,675
Wyoming....................	59,000	1,100	649	1,825
United States................	1,721,000	920	15,839	47,437

The acreage, production, and value of the dry, edible bean crop fluctuate from year to year, but there has been no marked upward trend in recent years as there has been in snap beans for market. In the states having low yields per acre, the crop is grown mainly under dry-land farming methods; where the yields are very large the crop is grown mainly under irrigation.

Part of the dry-bean crop grown in California, Idaho, Colorado, and Wyoming is produced for seed purposes.

History and Taxonomy.—The common bean is probably a native of South America and is undoubtedly of ancient origin. Many varieties were grown by the American Indians before they became generally cultivated in Europe.

It belongs to the family Legumnosae and is, therefore, closely related to the peas, clovers, and many other plants of great economic importance. Irish (1901) gives the following description of the plant.

> Plant sub-glabrous, dwarf or climbing 6 feet or more. Leaflets ovate-acuminate often oblique. Flowers in racemes shorter than the leaves, white or purplish violet, medium size. Pods flattened to sub-cylindrical, straight or curved, more or less turgid. Seed variable in size, shape, and color.

Soil Preferences.—Beans are grown on practically all types of soils from light sandy loams to heavy clays. In California peat soils are used for growing dry beans with very satisfactory results. In Florida, snap beans are grown on a large scale on the peat soils of the Everglades during the winter, spring, and early summer. In the North sandy and sandy-loam soils are preferred for an early crop of snap beans, but heavier, more retentive soils are desired for the growing of beans during midseason.

The bean plant does not produce large yields when grown on extremely acid soils. At Norfolk, Va., Zimmerley obtained the highest yields at reactions between pH 5.3 and pH 5.8 or 6.0. Similar results were obtained by Wessels on a silt-loam soil on Long Island. It would seem to be undesirable to apply lime for beans where the soil has a reaction of pH 5.5 or higher.

Fertilizers and Manures.—Authorities agree that the mineral elements phosphorus and potash are of greatest importance. This is undoubtedly true with field beans and with late-maturing varieties of garden beans, but for quick-maturing varieties, especially when planted early in the season some readily available nitrogen is needed. On sandy and sandy-loam soils of low productivity, a fertilizer application supplying from 25 to 40 pounds of nitrogen and from 50 to 80 pounds each of phosphoric acid and potash (1–2–2 ratio) is suggested for snap beans grown for market. On silt loams and clay loams, 20 to 25 pounds each of nitrogen and potash and 60 to 80 pounds of phosphoric acid (1–3–1 ratio) should be sufficient for snap beans grown for market.

Snap beans for canning are grown to a large extent in rotation with general farm crops and smaller quantities of fertilizer are used. The total returns for the crop do not justify so large investment in fertilizers for beans grown for canning as is justified for the market crop. Usually one-half the quantity of fertilizer suggested for snap beans grown for market would be satisfactory for canning-factory beans as they are commonly grown.

Field beans, such as the pea, medium, marrow, and kidney types, are generally grown as a farm crop and little or no fertilizer is used. Phosphorus is the element most commonly lacking in bean soils and is the one that gives the most profitable yields. Results of experiments conducted by Hardenburg (1930) at Ithaca, N. Y., indicate that applications larger than 300 pounds of 16 per cent superphosphate were not profitable. Under some conditions a light application of a complete fertilizer, similar to those suggested for snap beans, grown for the cannery, may be justified. Manure can be used to better advantage on other crops in the rotation.

Many experiments have shown that it is unsafe to apply fertilizer in the row in contact with the seed as the bean seems to be very susceptible to fertilizer injury. Results of experiments reported by Cummings *et al.* (1936) indicate that placement of fertilizer in bands 2 inches to each side of the seed, 1.5 inches below the level of the seed, was most satisfactory on fine sandy soil in Florida. Placement 3 inches below the seed gave good results, but is not so practicable as side placement. Other experiments have shown that side placement is much better than row placement or broadcast application.

Planting.—Common beans are tender to frost and are usually planted after that danger is over. Home gardeners and persons growing snap beans for the early market often take chances on frost and make a small planting before the danger is over. The main crop of green beans, especially those grown for the cannery, and all types grown for dry beans are planted after danger of frost is over and the soil has become warm. Where earliness is not an important factor, it is not advisable to plant beans until the danger of frost is past.

The rate of planting should be determined by the vigor of the type or variety, the richess of the soil, and the rainfall. Varieties producing large plants should be given more space than small-plant varieties, and on rich soils more space should be given than on a poor soil, provided rainfall is sufficient or irrigation is practiced. In dry farming sections more space is given than in irrigated or in humid regions. Most bush beans are planted in drills rather than in hills although the latter method is followed to some extent, especially in the Northwest. Seeds of field beans are planted 4 to 6 inches apart in the row with the rows 24 to 36 inches apart. Garcia (1917) recommends 6 to 12 inches apart in the row for Pinto beans, 6 inches giving the largest yield in experiments in New Mexico. Seeds of bush varieties of snap beans are commonly spaced

2 to 4 inches apart in the row with the rows 2 to 3 feet apart. Results of experiments conducted by Gillis (1928) in New York and in Illinois indicate that larger yields might be expected from closer planting of some of the common varieties. On a rather poor soil in New York, 9 plants per foot gave larger yields of the Red Valentine than either a larger or smaller number of plants. With the Refugee, 6 plants per foot gave the largest yield. On a more fertile brown silt-loam soil in Illinois, and with more favorable moisture conditions than prevailed in New York in 1923, 9 and 12 plants per foot produced considerably larger yields than either 3 or 6 plants per foot. A heavier rate of planting than is commonly practiced would probably increase the yield of most garden beans. Field beans are planted 4 to 6 inches apart in the rows 24 to 36 inches apart, but it seems probable that closer planting would increase yields in humid climates.

Pole beans are planted in hills, 3 by 3, 3 by 4, or 4 by 4 feet apart, 4 to 6 seeds in each hill, and then thinned to 3 or 4 plants if necessary. The poles are set before the seeds are planted and the hills are often raised a few inches to secure good drainage. Another method of planting this type of bean is to sow the seed in a drill the same as bush beans and use a wire trellis for supporting the plants. Some types of pole beans (cornfield beans) are planted with corn and the cornstalks serve as supports for the vines.

The quantity of seed varies greatly according to the size of seed and the spacing given. With pea beans 4 inches apart in rows 28 inches apart, 28 to 30 pounds to the acre would be required, while with the same spacing about 55 pounds of Red Kidney seed would be required to plant an acre. Gillis found that at the rate of six seeds to the foot it would require 75 pounds of Red Valentine, 90 pounds of Stringless Greenpod, and 60 pounds of Refugee seed to plant an acre with rows 3 feet apart.

Hendry (1918) recommends planting the Tepary, Red Mexican, Pink, Lady Washington, and Small White 6 to 10 inches apart in rows 26 to 30 inches apart. At 6 by 28 inches, 8.8 pounds of Tepary bean seeds would be required for an acre, 27.3 for Lady Washington, 32.6 for Pink, and 23.8 for Red Mexican.

The depth of planting varies, but beans should be planted no deeper than is necessary to get the seed into moist soil. The depth should be less on heavy than on light soils. In humid regions, 1 to 2 inches deep on heavy soils and 2 to 3 inches on light soils are usual. Garcia (1917) gives results of experiments in planting at different depths on wet soil (irrigated before planting) and on dry soil (irrigated after planting). The best germination on wet soil was at the depths of 3 and 4 inches. At 1 inch the germination was poor. On dry soil 1, 2, and 3 inches gave the highest germination, while the germination was very poor at 4 and 5 inches deep. Irrigating the soil after the seed is planted tends to pack the soil, and the surface soon loses its moisture; hence the germination is poor if shallow planting is practiced.

Cultivation.—Clean, shallow cultivation should be practiced. Deep cultivation is likely to cause injury by destroying the roots near the surface. Experiments carried on for 3 years at Ithaca, N. Y., show no benefits for the soil mulch. Good, shallow cultivation was compared with merely scraping the surface to keep down weeds. There were three plots in each treatment and the results were consistent and showed no benefit from the cultivation other than weed control.

A study of the root system showed that most of the roots were in the surface 6 or 8 inches of soil with some 1½ to 2 inches deep. The main root zone was between the depths of 3 and 8 inches from the surface. The roots are fairly plentiful 24 inches below the surface, especially immediately under the row, and some reached the depth of 30 inches.

When the plants reach full size, cultivation is likely to do more harm than good unless there is considerable weed growth. Cultivation should not be given when the vines are wet, since the spores of the fungus causing anthracnose are easily carried from diseased to healthy plants at such times.

Supporting Pole Beans.—Poles 8 to 9 feet in length are usually employed to support climbing varieties of beans. The bark and stubs of the small branches are left on the poles as the rough surface is an advantage to the plants. The poles are set in the ground to the depth of 18 to 24 inches before the beans are planted. If the poles are kept under cover when not in use, they will last several years.

Various forms of trellis supports are used to some extent. Heavy posts are set at the ends of the rows and lighter posts or stakes are set at intervals of 20 to 25 feet, then two strands of No. 10 wire are fastened to the posts, one at the top and one near the ground. Light twine is used to connect the two wires. The twine is fastened to the lower wire then passed over the upper wire and back under the lower one and continued in a zigzig fashion to the end of the row. The bean plants twine around the string until they reach the upper wire. This method of supporting the vines makes picking less difficult than when poles are used, but is expensive.

Varieties.—Varieties of beans are listed under hundreds of names, many of which are synonyms. Jarvis (1908) found that the Red Valentine variety was listed under 67 different names; other well-known varieties have many synonyms. He described 150 true varieties as follows: 40 dwarf wax-podded, 75 dwarf green-podded, 10 climbing wax-podded, and 25 climbing green-podded. Tracy (1907) described 185 varieties.

Various methods of classification of varieties of beans have been developed. Irish classified them on the basis of seed, pod, and vine characters; Tracy based his classification largely on vine, pod, and blossom characters; Jarvis based his classification and key entirely on the seed, but in the description of varieties the plant characters were used. All of these workers give comprehensive keys to cultivated varieties and complete detailed descriptions of those grown in the United States.

Varieties of beans may be classed according to their uses as (1) snap beans, those grown for the edible pod; (2) green-shell beans, those used in the green-shelled condition, and (3) dry-shell beans or ripe seed, those used in the dry state. Beans are also classed according to the color of the pods as, green-podded and yellow- or wax-podded. For convenience in grouping, beans are divided into dwarf or bush varieties and climbing varieties, and as field and garden beans. The term "field beans" is usually applied to those grown for use in the dry state and includes four types, kidney, marrow, medium, and pea. Gilmore (1905) suggested the following key for the identification of the four types of field beans:

Seed 1.5 cm. or more in length, more or less reniform, ratio—length, width, thickness 1–0.4869–0.3731—Kidney.

Seed between 1 and 1.5 cm. in length. Thickness exceeding half the length, 1–0.6537–0.6029—Marrow.

Seed 1 to 1.2 cm. in length. Thickness less than half the length 1–0.678–0.4975—Medium.

Seed .8 cm. or less in length, not reniform 1–0.7467–0.6096—Pea.

Some of the most important varieties of field beans of the various types are the following:

Pea beans: Boston Small Pea, Marrow Pea, Medium Pea, Snowflake, Navy, Michigan Robust. The last named is resistant to the mosaic.

Medium: White Wonder, Burlingame Medium, Blue-pod Medium.

Marrow: Yellow Eye; White Marrow, Red Marrow.

Kidney: White Kidney, Red Kidney, White Imperial and Wells' Red Kidney.

The last two are especially desirable where anthracnose is serious as they are resistant to this disease.

Some of the important varieties of garden beans in the various classes are as follows:

Bush green-podded: Bountiful, Tendergreen, Giant Stringless Greenpod, Stringless Black Valentine, and Stringless Green Refugee. The Stringless Green Refugee is especially important for canning.

Bush wax-podded: Pencil Pod, Wardwell's Kidney Wax, Webber Wax or Crackerjack Wax, Round Pod Kidney Wax or Brittle Wax, Sure Crop Wax, and Refugee Wax (for canning).

Climbing green-podded: Kentucky Wonder or Old Homestead, Scotia or Creaseback.

Climbing wax-podded: Golden Cluster and Kentucky Wonder Wax.

Seven of the important varieties of bush snap beans are shown in Fig. 58.

Diseases.—Beans are subject to several serious diseases such as anthracnose, bacterial blight, mosaic, dry root rot, and rust and also to a few of minor importance. Burkholder (1923) gave the following descriptive key to the more common diseases affecting the bean:

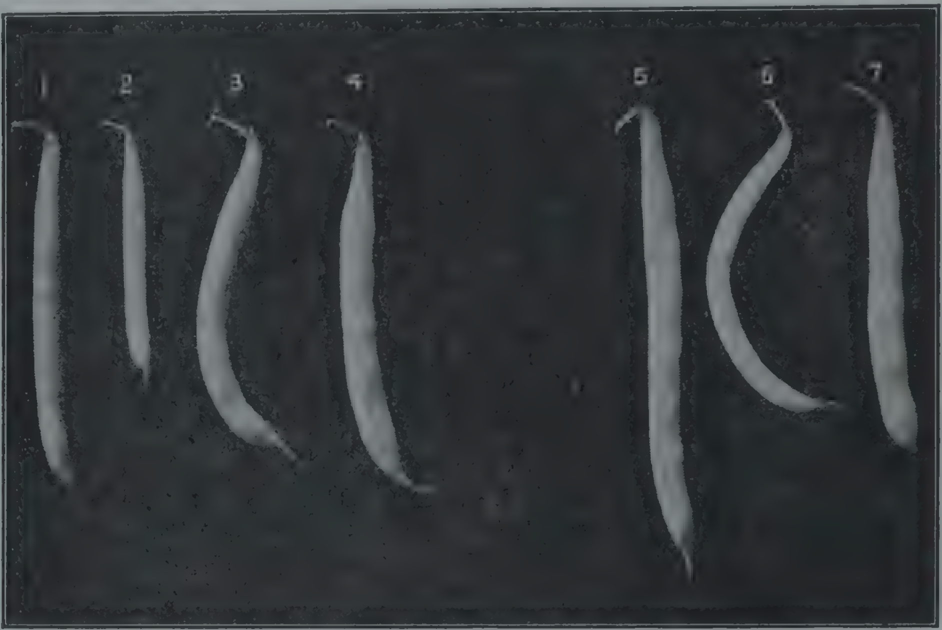

Fig. 58.—Varieties of bush snap beans. Green-podded: 1, Black Valentine; 2, Stringless Green Refugee; 3, Giant Stringless Greenpod; 4, Bountiful. Wax-podded: 5, Davis White Wax; 6, Pencil Pod Black Wax; 7, Wardwell's Kidney Wax. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

A DESCRIPTIVE KEY TO BEAN DISEASES

On the Plants above Ground

1. Areas on veins on under sides of leaves turn black; dark, circular sunken spots appear on pods, and similar spots are found on the stems of the seedlings; most serious in rainy seasons..Anthracnose

2. Large, brown, dead areas form on the leaves; watery, irregular spots appear on the pods, and these later turn reddish and become sunken; at times there is a rotting of the stem at the first joint.................................Bacterial blight

3. A tipburning of the leaves and a dwarfing of the plant occur; also, a decided wilting of a part, or the whole, of the plant........................Bacterial blight

4. Dwarfing, mottling, and crinkling of the leaves occur; in many instances, the plant grows bushy and remains green until frost; few or no pods set; found more generally on the pea and medium varieties of field beans..................Mosaic

5. Small, powdery, brown pustules occur on the leaves, stems and, less frequently, on the pods; disease appears late in August..............................Rust

6. A rotting of the stems and the pods of the plant takes place, accompanied by a cottony growth, and small, black, hard bodies about ⅛ or ¼ inch in diameter are formed; disease occurs in rainy season, or in damp, shady places. . . Sclerotinia rot

7. Plants dwarfed; such varieties as the marrow and pea fail to vine; few pods produced; leaves turn yellow and drop prematurely; more severe in dry weather. Dry root rot

On the Plant Parts below Ground

1. Taproot is at first red, but later becomes brown and dried; frequently a mat of surface roots produced; more serious in dry weather. . . . . Dry root rot

2. Taproot reddish at first, but later coal-black lesions with a frosty appearance in wet weather form on roots; most severe on seedlings and in cool weather. Black root rot

3. Brick-red, sunken blotches on lower stem and on taproot; seldom severe. Rhizoctonia blotch

ANTHRACNOSE.—This disease is caused by the fungus *Colletotrichum lindemuthianum* which attacks the stems, leaves, pods, and seeds. On the stems and leaf veins it causes elongated, sunken, dark-red cankers. On the pods the disease causes rounded or irregular sunken spots with pink centers surrounded by a darker reddish border. In severe cases the pod may be entirely covered by the spots and produce no seed. In other cases the fungus penetrates the pods and enters the seed, causing dark spots. Diseased seeds and refuse from diseased plants carry the fungus from season to season.

No control measures have been found that will keep this disease in check once it has started to develop. Use of disease-free seed and anthracnose-resistant varieties are the methods used to avoid serious losses. A large part of the Red Kidney seed used is grown in areas in California and Idaho that are free from both anthracnose and bacterial blight. Much of the snap-bean seed is grown in Idaho and is free from anthracnose. Wells' Red Kidney is resistant to anthracnose as is the Robust pea bean, the Perry Marrow, the Geneva, the York, and Nova Scotia Marrow. In regions where anthracnose is present, seed should not be saved for planting from plants that have been grown from seed of non-resistant varieties.

BACTERIAL BLIGHT.—This is a bacterial disease caused by *Phytomonas phaseoli* which produces small irregular, amber-colored areas that have a water-soaked appearance at first. These areas enlarge rapidly and may involve the whole plant. Infected seed show yellow blotches or become yellowed all over.

Bacterial blight is controlled in the same way as anthracnose by obtaining seed from regions that are free from the disease, as parts of California and Idaho. Robust, Yellow Eye, some of the Marrows, and some of the Refugee strains are resistant in varying degrees.

Mosaic.—This disease is apparently due to a virus that is transmitted from diseased to healthy plants in some way. It appears mainly on the leaves in the form of light- and dark-green areas. The leaves affected by mosaic show a distinct downward cupping. Mosaic is not a serious disease in many bean-growing regions, but is serious in New York.

The use of resistant varieties is the only safe way of controlling this disease. The Michigan Robust is very resistant. Only the varieties of pea and medium types of field beans seem to be very susceptible to this disease. The Red Kidney, White Marrow, Yellow Eye, and most varieties of snap beans are not injured to any great extent by it. U. S. No. 5 Refugee, developed by the U. S. Department of Agriculture and described by Wade and Zaumeyer (1938), is said to be very resistant to mosaic.

Dry Root Rot.—This disease is caused by the fungus *Fusarium* spp., and is a serious trouble in the older bean-growing regions of New York. The most pronounced symptom of this disease is a more or less stunted plant with a partly decayed taproot. The fungus affects all parts of the plant below ground and all types of beans are attacked. The fungus lives over winter in bean refuse left in the field or in manure from livestock fed on diseased bean straw.

No satisfactory control measures have been found for this disease. Long rotations, 6 years or longer, and disposal of bean straw in such a way that it is not put on land to be planted to beans are helpful. Robust and a few other common varieties are fairly resistant and should be grown where the disease is serious.

Rust.—The rust caused by *Uromyces appendiculatus* is very widespread, but is not considered serious in most bean-growing states. It is, however, serious in Virginia, West Virginia, Tennessee, Georgia, Louisiana, and Southern California. The losses due to the rust are indirect, being due to decreased vigor on account of foliage injury.

This disease should not be confused with anthracnose which is sometimes called "rust." The seed catalogues use the name rust for anthracnose and their so-called "rust-proof" or "rust-resistant" varieties are supposed to be resistant to anthracnose. The rust attacks the leaves chiefly and all of the injury results from infection of the leaf. The leaves are covered with small, reddish-brown spore masses. Within a few days after the rust pustules appear, the leaf begins to turn yellow and later brown, then it dries up and drops off.

Fromme and Wingard (1918) recommend the use of rust-resistant varieties as follows:

> Dry shell beans: Dwarf Horticultural and Red Kidney, for colored beans; White Marrow and White Kidney for white beans. Avoid Navy, Snowflake, Pinto, Pink, and Tepary.

Pole beans: Horticultural Pole, Lazy Wife for green-pods and Mont. d'Or for wax-pod. Avoid Kentucky Wonder, Creaseback, Virginia Cornfield, etc.

Green-pod beans: Black Valentine, Burpee's Stringless, Hodson Green-pod, Low's Champion, Refugee, and Warren.

Wax-pod beans: New Pearl and Pencil Pod.

Bean Insects.—Many insects attack the bean, the most important being the Mexican bean beetle, the bean weevil, bean leaf beetle, bean thrips, bean aphis, and the bean fly or seed-corn maggot.

MEXICAN BEAN BEETLE (*Epilachna corrupta*).—This is the most serious insect pest attacking growing beans in regions where it is abundant. It is a serious pest in most of the important bean-growing sections of the United States, except the Pacific coast states, the Northwest, and in parts of other northern states.

The Mexican bean beetle feeds mainly on the common bean and the Lima bean, but if these are not present the insect will feed on cowpeas, soybeans, alfalfa, sweet clover, and beggarweed. Both the adult and the larva are injurious and, when present in abundance, they feed on all parts of the plant. The larva feeds entirely on the underside of the leaf and eats the epidermis of the blade, leaving the midribs and veins and usually the upper epidermis. The adult also feeds from the underside, but frequently eats through the upper surface.

The adult beetle is nearly hemispherical in shape, about ¼ inch long and ⅕ inch wide. The color of the adult ranges from orange to copper. Each of the two wing covers bears eight black spots. The larva is orange colored, varies in length from about 1/20 inch when young to about ⅓ inch when full grown, and is covered with long, branched spines.

The best control measures for this beetle is dusting with a derris powder containing 0.75 per cent rotenone. Good results can be obtained by spraying with 5 pounds of finely ground rotenone-bearing powder (containing 4 per cent of rotenone) in 100 gallons of water. Magnesium arsenate may be used as a dust or as a spray for control of this insect up to the time that the blossoms develop, but should not be used after the pods form. For dusting, 15 pounds of magnesium arsenate to 85 pounds of hydrated lime is recommended. For spraying, 3 pounds of the arsenate and 9 pounds of hydrated lime to 100 gallons of water is a common formula.

Poisons should be applied as soon as the eggs are found or as soon as the adults appear in sufficient numbers to do noticeable damage. Additional applications should be made at intervals of 3 to 7 days until the pest is under control. To be effective, poisons should be applied to the lower surface of the leaves. Dusts should be applied in the morning while the dew is on the plants, especially if small machines are used.

Sprays should be applied when the plants are dry. Arsenical poisons should not be applied to the plants while they are in the bearing stage. Poisonous residues have been found in injurious quantities on unwashed beans. Rotenone preparations may be used at any time as they do not leave a poisonous residue. Some growers use arsenicals in the early stage of growth and rotenone preparations after the pods form.

BEAN WEEVIL (*Bruchus obtectus*).—This insect is a small dull-colored beetle found in stored beans. The eggs are laid in the pods in the field and the larvae or grubs develop in the seeds and transform into beetles in cavities just under the seed coat. The beetle cuts a circular opening through the seed coat in emerging. Several beetles may develop in a single seed. In the South there may be six or more generations in a year, but in the North there is usually only one. Where there is more than one generation the breeding may be continuous in storage. The number of generations depends on the temperature.

Beans infested with weevils should not be planted since the germination is likely to be poor. The weevils in the beans can be killed by fumigating with carbon disulphide at the rate of 3 to 8 pounds to each 1,000 cubic feet of space to be fumigated, the amount to be used varying with the tightness of the container and the temperature. The liquid should be poured over the top of the seeds to be fumigated. It quickly vaporizes and the gas, being heavier than air, sinks to the bottom of the container, filling the air spaces. For best results, the temperature should be 75°F. or above. It is not effective at 60°F. or below. For fumigating small quantities, place the beans in a tight receptacle and use 1 ounce to each bushel to be fumigated. Heating the beans to 120° to 145°F. for several hours also destroys the weevil. At low temperatures the insects do not feed and cause damage; hence cold storage prevents injury.

In addition to the common bean weevil there are several other species that attack beans, but the same control measures are effective for all of them.

BEAN LEAF BEETLE (*Cerotoma trifurcata*).—This insect is a small beetle, about ⅓ inch long, yellowish to reddish, and has six black dots on the wing covers. The beetles eat large holes in the leaves, feeding from the underside. The eggs are laid on the ground at the base of the plant and the grubs feed on the roots and the main stem just below the surface. From one to three broods occur each year, depending on the length of the growing season.

Spraying or dusting with arsenicals, as recommended for the Mexican bean beetle, would probably be effective in controlling this insect.

BEAN THRIPS (*Heliothrips fasciatus*).—In the Far West this insect sometimes injures the bean crop seriously. The adult insect is about 1/25 inch long, grayish black in color. Infested leaves of the bean plant turn pale and drop off. The pod takes on a silvery-white appearance.

This insect is seldom injurious enough to justify special control measures. If the plants are kept in a thrifty condition they can usually withstand the attack, but when necessary to spray, nicotine sulphate, 40 per cent, 1 part to 800 parts water, to which soap has been added will control this insect. The spray should be applied to the underside of the leaves.

Bean aphid (*Aphis rumicis*) is a small, black plant louse, widely distributed, but is especially injurious in California. The insect passes the winter in the egg stage on various cultivated shrubs. It feeds on many vegetables and on many common weeds.

The aphids may be controlled by spraying with nicotine sulphate if they are actually hit by the spray.

Seed-corn Maggot (*Hylemyia cilicrura*).—The adult fly is somewhat smaller than the housefly and is greenish gray in color. The larva is a small white maggot, about ¼ inch in length. It feeds on the sprouting seeds, and on the plumule. Later it burrows into the cotyledons and sometimes through the radicle.

No satisfactory control measure has been worked out for this insect. Beans on heavy, wet soils are more likely to be injured than those grown on lighter, drier soils. Drainage of wet fields is, therefore, recommended. Shallow planting is advised when the soil is wet.

Harvesting.—Snap beans are usually harvested before the pods are full-grown and while the seeds are small. Most varieties get tough and stringy if left on the plants until the seeds develop to full size. Picking is done entirely by hand and the amount of labor required restricts large-scale production to localities having an abundant supply of labor which can be had at any time. Since bean plants continue to bear over a considerable period of time it is necessary to make several pickings.

Unless great care has been used in picking, it is desirable to have the beans sorted to pick out over-mature pods and those that are broken or injured by diseases, insects, or other means. Snap beans are packed for shipment in hampers, stave and tub baskets, and special boxes or crates. The package should be well filled by shaking the container as it is being packed.

Snap beans can be kept in storage for several days at about 40°F. and at humidities above 90 per cent. Results of experiments by Platenius *et al.* (1934) show that beans kept better at 40°F. than at either 32°F. or 50°F.

When beans are transported long distances during warm weather, they are shipped in refrigerator cars.

Harvesting Dry Beans.—Dry beans are harvested as soon as a large percentage of the pods are fully matured and have turned yellow. As most varieties do not ripen evenly, it is desirable to watch the field and to begin harvesting before the lower pods get dry enough to shatter. Some varieties shatter more than others. Teparies shatter very badly and Red Kidney drops its seed if allowed to remain standing until the pods are fully dry.

Small areas of dry beans are pulled. When grown on a large scale, bean harvesters are commonly used. These machines are equipped with cutting bars which cut off the plants below the surface of the ground. Guard rods, attached above the cutting bars, move the bean plants after they have been cut. Two rows are usually cut at one time and the plants are thrown together into one row. The vines are left in the windrow, or thrown together into small piles and left for several days to cure. If the vines are still green when harvested, they should be left in the windrow until they become fairly dry. After curing a while in the windrow or in small piles, they are hauled to the barn where they are stored until they are threshed. Formerly beans were stacked in small stacks in the field, but this practice is seldom followed in the main bean-growing sections of the eastern portion of the United States at present. In sections of the West, they are stacked in small stacks (four or five wagon loads) although larger ones are sometimes used. In California the beans are cured in small cocks similar to those used in curing hay.

Threshing.—Beans are commonly threshed with machines similar to grain threshers. The common type of thresher used for beans has two cylinders which are run at lower speeds than is common in threshing wheat, rye, etc. Grain threshers are sometimes used, but they are unsatisfactory, even when the speed is reduced to 300 or 400 revolutions per minute. The combined harvester and thresher is also used to some extent in California. The beans are left in the windrow until thoroughly cured, when they are picked up by the movable threshing machine driven by its own power or pulled by a tractor.

Thresher injury is rather severe in certain varieties of garden beans and Lima beans. According to Harter (1930) the epicotyl is fractured just below the plumule and this results in a condition known as "baldhead" in which the growing point and part or all of the primary leaves are absent in the seedling plant. Baldhead plants produce few or no pods.

SCARLET RUNNER OR MULTIFLORA BEAN

The Scarlet Runner (*Phaseolus coccineus*), also called Multiflora bean, is probably a native of Central America or South America, although it was formerly supposed to have been indigenous to Asia. In America it is grown mainly as an ornamental climber; the spikes of rich scarlet flowers and the deep green foliage make it one of the most showy and attractive plants. In Europe this bean is used as food. The tender, green pods only are eaten in some localities, while in others the green and dry seeds are used.

The plant grows 12 feet or more in height and requires 115 to 120 days to mature its seeds. In germinating, the Scarlet Runner differs from other species of Phaseolus in that the cotyledons remain in the ground and the germination is known as hypogeal. The plant produces a thickened root somewhat like the Dahlia, though smaller.

LIMA BEANS

The name Lima bean, as used here, includes the large-seeded (*P. limensis* formerly *P. lunatus* var. *macrocarpus*), and the small-seeded sieva (*P. lunatus*). Lima beans are grown for local markets, for shipment, and for home use in fresh condition in the South and East, and to some extent in other regions. The estimated annual acreage of green Lima beans grown for market during the period 1933 to 1937 was 11.460 acres, producing 647,000 bushels valued at $846,000. The leading producing states were New Jersey, Florida, North Carolina, Georgia, South Carolina, Maryland, and Virginia. During that 5-year period the average annual acreage of Lima beans grown for manufacture was 28,680 acres, producing 16,876 tons valued at $1,039,000. The leading producing states were New Jersey, Delaware, Virginia, Maryland, Michigan, and Wisconsin.

Lima beans are grown for use in the dry-shelled state, mainly in California. According to figures published by Wellman and Braun (1927) California produced 1,250,000 bags (of 100 pounds each) of Lima beans and 575,000 bags of baby Limas (Henderson's Bush) in 1926. They estimate the normal production at 850,000 and 400,000 bags respectively.

History and Taxonomy.—Linnaeus believed that the Lima bean was of African origin, but it is now known to be of tropical American origin, probably South America. Seeds have been found in Peruvian tombs and the plant has been found growing wild in Brazil. Sturtevant states that in southern Florida, the Lima bean is found growing spontaneously in abandoned Indian plantations. It is now widely distributed, but since it requires a warm season it is not grown so much in northern Europe as in the United States.

Jarvis (1908) gives the following descriptions of the sieva and the true Lima beans:

SIEVA.—Plant annual, climbing or dwarf, frail, slender branches; leaflets moderately small, ovate, acuminate (one garden variety has linear-lanceolate leaflets), thin, smooth, glossy, dark-green; flowers small, white or greenish-white in axillary racemes; pods 2 to 4 inches long, ½ to ¾ inch broad, curved, well-defined point or spur, 2 to 4 seeded, green; seeds small, flat, subreniform, with distinct lines radiating from the hilum to the dorsal margin, variously colored.

Lima.—Plant perennial in the South, grown as an annual in the North, vigorous grower, climbing or dwarf; leaflets large, ovate or ovate-lanceolate, thick, stiff, slightly pubescent, dull green; pods large, 3 to 6 inches long, 1 to 1¼ inches broad, flat frequently twisted, point or spur very short or wanting; seeds very large, usually very flat and reniform (the potato type quite turgid and subreniform), variously colored It differs from the sieva type chiefly in being perennial (in the South), in making a large growth, in being less hardy, later in season, and in having larger leaves and pods. Many strains, differing chiefly in season and size of pod, are in cultivation. The type of many of these modified forms is not well fixed and, for this reason, it is difficult to make accurate descriptions and comparisons.

Culture.—In general, the culture of both types of Lima beans is practically the same as for the common or kidney bean. The Lima, especially the large type, is less hardy to cold than the common bean and should not be planted until all danger of frost is over and the soil has become warm, since the seeds rot in cold soil. It also requires a longer growing season than the common bean. The pole varieties of large Lima do not produce satisfactory crops in regions having less than 4 months' frost-free period, with warm weather, including warm nights for a considerable portion of this period. The main producing regions of Lima beans are the southern states and California, the latter producing practically all the dry Limas. In the northern states, the bush varieties of both the sieva and Lima beans are more generally grown than the climbing varieties. The large type is less hardy and requires a longer season than the sieva types, hence the latter is grown to a greater extent than the former in regions having a relatively short season. Climbing varieties, as a rule, require more time to mature than the bush or dwarf.

In the northern border states the climbing varieties of large Lima do not mature enough crop before frost in autumn when planted direct to the garden to justify growing. However, by starting the seeds in pots, paper bands, berry boxes, or tin cans in a greenhouse or hotbed 3 or 4 weeks before it is safe to plant in the open, a satisfactory yield is often secured. Even by this method the yield is low in regions having cool nights for a considerable portion of the growing season.

On light soils Lima beans mature earlier than on heavy soils, hence in regions having a short growing season the lighter types should be selected, provided other conditions are favorable. In regions with a long growing season soils heavier than the sands and sandy loams are preferred.

One of the serious problems in growing Lima beans, especially the large-seeded varieties, is failure of the blossoms to set seed. High temperature and low atmospheric humidity seem to be important causes for this failure. Andrews (1936) has shown that under high temperature and low relative humidity the plants fail to set and mature a normal crop of seed, but that under such conditions the Henderson variety produces a larger crop than does the Fordhook. When grown under relatively cool or moderate temperatures and relatively high humidity, the Fordhook often surpasses the Henderson. Andrews suggests that the larger yields from the Henderson than from the Fordhook under unfavorable conditions is explained by the relatively greater root system and the more efficient leaves of the Henderson.

Supporting the Vines.—Climbing varieties of Lima beans are usually supported as mentioned for the climbing varieties of kidney beans; in California, where they are grown for dry beans, the plants grow on the ground. The climbing varieties of large Limas are planted in rows 2½ to 3 feet apart with the seeds 6 to 12 inches in the row. The plants spread across the row and form a mulch that prevents rapid evaporation. Since the crop is grown in California during the dry season, the vines sprawl on the ground with no injury to the pods.

Varieties.—Both the sieva and the true Lima beans contain dwarf or bush and running types. Among the varieties of dwarf sieva or Carolina beans Henderson's Bush Lima (Dwarf Sieva and Dwarf Carolina) is the best known. Carolina or sieva, the "Butter Bean" of the South, is the most important variety of climbing sieva beans. Of the true Lima, Burpee's Bush and Fordhook Bush are well-known varieties of bush Limas. Early Leviathan, Challenger, and Lewis are the most important climbing or running varieties.

Diseases.—Lima beans are not seriously affected by disease in most regions; in some sections bacterial spot and downy mildew cause considerable losses in some years.

BACTERIAL SPOT.—This disease is caused by *Bacterium Vignae* Gard. and Kend. According to Clayton (1928) it attacks all of the aboveground portions of the plant, causing the development of lesions of a reddish-brown color. The most serious phase of the disease on Long Island is on the pods. The young diseased pods often drop off of the plant, resulting in a reduction in yield. Clayton believes that the organism lives over in the soil and, perhaps, also on the seed.

Spraying experiments, conducted by Clayton on Long Island, showed that the damage from the disease was greatly reduced by spraying with Bordeaux mixture. Leaf injury was greatly reduced and the set of pods was increased by spraying.

DOWNY MILDEW.—This disease is caused by *Phytophthora phaseoli* Thaxt. It is primarily injurious to the pods, attacking them in all stages of growth from flower to maturity. The older, diseased pods show the thick, white growth of mycelium that is characteristic of downy mildew.

This disease is often serious on Long Island and, according to Clayton, it appears in the field between Aug. 1 and 15. It spreads rapidly in wet weather and may cause serious losses.

Clayton recommends two applications of Bordeaux mixture, 7 to 10 days apart, just before the plants are in full bloom, and three to six applications following at 7-day intervals. In dry seasons, spraying may be discontinued early. Clayton recommends Bordeaux mixture of normal strength or stronger. He emphasizes the necessity of arranging the nozzles so that the spray will hit the plants from the sides rather than from above. Two nozzles should be used to each row. Copper-lime dust gave fairly good control, but not so good as liquid Bordeaux. Clayton suggests either a 15–85 or 20–80 copper-lime dust without poison.

Harvesting.—Lima beans, grown for use in the green-shell condition, are picked by hand when the seeds have become nearly or quite full-grown, but before the pods turn yellow. Half-grown beans sell for a higher price than the full-grown ones, but the yield is lower and they are more difficult to shell.

Lima beans grown for canning are cut with mowing machines and the vines with the pods are hauled to the vining station or to the cannery where the beans are shelled by machinery.

Dry Lima beans are harvested in very much the same way as common field beans. In California a cutter is used which cuts two rows at a time and both rows are pushed together in the middle. The vines are left in the windrows for a few hours and then piled by hand with pitchforks. Three windrows are commonly brought together in one row of piles. These piles are 4 or 5 feet in diameter on the ground and 3 feet high. They remain in these piles until they are very dry, the time depending on the weather and the maturity of the beans, but usually from 2 to 3 weeks.

Threshing.—Lima beans are threshed with a machine similar to a grain thresher. When machine-threshed Lima beans are used for seed, a rather large percentage of the seedlings is likely to be defective resulting in a reduced yield. In addition to baldhead, discussed in connection with the common bean, Borthwick (1932) has described three types of injury as follows: (1) one or both cotyledons may be broken from the embryo; or, in other cases where they still adhere to the plant, they may be injured to such an extent that the food reserves are not efficiently translocated; (2) injury to the radicle results in complete loss; (3) the hypocotyl may be broken, in which case, if the break is near the top, the cotyledons remain below ground when germination occurs.

After threshing, the beans are stored in warehouses until they are to be marketed, when they are recleaned. A machine is used for this and for separating the split beans from the whole ones. The beans are marketed in bags.

Preparation of Green Lima Beans for Market.—Lima beans, to be sold in the fresh condition, should be picked as soon as the beans have attained full size and before they turn white. While they keep better in the pod, some markets demand them in the shelled form; as the shelling is tedious and expensive, it limits the production of the crop for market. Shelling is made easier if the pods are allowed to wilt for a few hours before shelling, but care should be taken to prevent heating.

Shelled green Lima beans are subject to spotting and stickiness, which could be avoided by marketing them in the pods. Brooks and McColloch (1938) have shown that the spotting is caused by a fungus and the stickiness by bacteria, both of which are spread to the beans in the process of shelling. Lowering the humidity of the storage atmosphere resulted in a decrease of both stickiness and spotting but did not give satisfactory control. Washing the beans in a 30 per cent solution of ethyl alcohol or washing in a 4 per cent solution of chlorinated lime gave complete control of spotting and good commercial control of stickiness.

When green Lima beans are sold as shelled beans, the shelling is done by hand and the beans are put in berry boxes and crated. It would seem to be a better practice to sell the beans in the pods and let the consumer do the shelling as is the practice in many markets.

TEPARY BEAN

The tepary bean (*Phaseolus acutifolius* var. *latifolius*) is probably native of southwestern United States and northern Mexico and was domesticated by prehistoric Indian races. Freeman (1912) states that 47 distinct types have been isolated and grown at the Arizona Experiment Station.

Tepary beans are especially valuable in the arid regions of the Southwest and in similar regions of Mexico and elsewhere. They withstand extreme heat and dry atmosphere better than any other type of bean.

Freeman writes as follows regarding the botanical relationship of the tepary:

> The tepary differs from both the kidney bean (*Phaseolus vulgaris*) and the Lima bean (*Phaseolus lunatus*) in several marked botanical characters. The seeds are smaller, averaging 0.15 grams, while the kidney beans average 0.23 grams and the Limas average 0.50 grams or more. When present at all the markings or flecks on teparies are much finer than on the other two. The seed coat of the tepary lacks the characteristic glossiness of the kidney bean.
>
> The length of the petioles of the first pair of aerial leaves is strikingly different in the tepary and in *Phaseolus vulgaris* and *lunatus*. Measurements of

> the mature petiole of the first pair or aerial leaves on a large number of seedlings of several varieties of each gave the average of the tepary 4.3 mm., for kidney beans 24.33 mm., and for the Limas 43.7 mm. The first two pairs of aerial leaves of all three species are simple, but those of the tepary differ from the others in having truncate instead of cordate bases. They are also smaller and narrower . . .
>
> . . . The flowers of the tepary are smaller than those of the kidney bean, the wings are narrower in comparison with their length and the banner is more strongly reflexed in flower . . .

The culture of the tepary bean is not very different from that given the common kidney bean under similar conditions. Freeman suggests planting in rows 3 feet apart with the seeds spaced 6 inches apart in the furrow and covered to a depth of 4 inches, or else in hills 18 inches apart with two to four seeds in a hill. "It is important that the seeds be covered immediately following the opening of the furrow if quick germination and a uniform stand are to be insured."

Teparies are now grown in Arizona, New Mexico, and in sections of California, especially in the hot, dry interior valleys.

After a very careful study of the native beans of the Southwest, Freeman gives the following summary:

> The peculiar climatic conditions of the semiarid, subtropical Southwest are most favorable, usually, only to the varieties of crop plants which have been long grown in the region, or in similar regions.
>
> Among the Indians of the Southwest may be found varieties of corn, beans, and squashes that have been grown within the present confines of Arizona for hundreds or perhaps thousands of years. Centuries of adaptation have, therefore, produced types well suited to withstand the extremes of heat and drought to which the climate often exposes them.
>
> Native-grown beans, the subject of this bulletin, are among the most successful of these acclimated crops.
>
> Two different types of beans have been collected from the Indians of southern Arizona, recognized by them as distinct and commonly known by the Mexican names, "Frijoles" and "Teparies."
>
> Botanical study has established the fact that these two types are different species. Frijoles belong to the group of common kidney beans (*Phaseolus vulgaris*, Linn.); while teparies, heretofore unrecognized in horticultural literature and unknown to botanists except as a wild species, belong to that large and variable group described by Gray as *Phaseolus acutifolius.*
>
> Frijoles, now grown in the Southwest, are probably descendants of varieties introduced by the early Spanish missionaries. Twenty-three distinct varieties have been tested at this Station, among the most promising of which may be mentioned the Pink bean, the Bayou, the Hansen, the Garaypata, and the Red Indian.
>
> Teparies, also grown by southwestern Indians, were probably not domesticated from the type form of *Phaseolus acutifolius* A. Gray, but from a larger,

more robust, broad-leaved variety of the species such as was collected by Wright in a valley of Sonora as early as 1854, and described by Gray as distinct, but left unnamed by him probably on account of lack of material, which is now abundantly available.

The tepary (*Phaseolus acutifolius* A. Gray) is, therefore, added to the list of species of beans used as esculents and it is suggested that this form be called *Phaseolus acutifolius* var. *latifolius.*

The tepary was domesticated from wild plants growing in the canyons of the southwestern United States and northern Mexico by prehistoric Indian races. Being variable in the wild state it has responded during domestication by the production of many varieties. Forty-seven distinct types have been isolated and grown at this Station. Among the most promising sorts may be mentioned the White Tepary.

SOYBEAN

The soybean (*Glycine Max.* or *Soja Max.*) is a native of southeastern Asia and has been cultivated in Japan and India since ancient times. Hundreds of varieties are grown in these countries and in China. In the extent of uses and value it is the most important legume grown there. The soybean was first introduced into the United States as early as 1804, but it is only within the last 40 to 50 years that it has become of much importance. It is now grown mainly for feed and oil in this country, although there is interest in the crop for the manufacture of plastics and for use as human food.

In Asiatic countries, especially China and Japan, the soybean is second in importance to rice as a food crop. Morse (1918) gives the following uses for it and the food products made from the seeds:

- Meal
  - Human food
    - Breakfast foods
    - Diabetic foods
    - Flour
      - Bread
      - Cakes
      - Muffins
      - Biscuits
    - Infant foods
    - Macaroni
    - Crackers
    - Milk
  - Stock feed
  - Fertilizer
- Oil
  - Industrial uses of various kinds
  - Food Products
    - Butter substitute
    - Lard substitute
    - Edible oils
    - Salad oils
- Dried beans
  - Soy sauce
  - Boiled beans
  - Baked beans
  - Soups
  - Coffee substitutes
  - Roasted beans
  - Vegetable milk
    - Cheese
      - Fresh
      - Dried
      - Smoked
      - Fermented
    - Condensed milk
    - Fresh milk
    - Confections
    - Casein
  - Breakfast foods

Green beans
- Green vegetables
- Canned
- Salads

The plants are used for green manure, for forage, for silage, and for pasture.

The soybean has about the same climatic adaptations as corn. Morse states that it is especially adapted to the cotton region of the United States and northward to the Ohio and Potomac Rivers. In the latter region the larger and later varieties, which give yields that make their extensive cultivation very profitable, can be grown.

> Recent introductions of early maturing varieties from northern Manchuria mature profitable yields of seeds in the northern tier of states, while the later varieties can be grown for hay or ensilage.

In the lower sections of the Gulf Coast and in the Southwest where extreme hot weather prevails during the period when the pods are maturing, the yield of seed is small.

The soybean is quite drought resistant and but for the depredations of rabbits it would be a valuable crop in the semiarid West.

Culture.—The time to plant soybeans depends on the length of the growing season and the use to be made of the crop. In general the crop may be planted about the same time as corn, although in the South soybeans are planted as late as August. When grown for seed, the crop is usually planted in rows about the same as common beans; for hay or for green manure, broadcast sowing is the common practice. Planting in rows is preferred by some authorities for all purposes.

The crop is harvested and handled about the same as cowpeas.

COWPEA

The Cowpea (*Vigna sinensis*) is probably a native of central Africa. Piper (1913) reports that a wild plant differing little from the cowpea occurs throughout a large part of Africa. Hybrids of this plant and the cultivated cowpea are readily obtained. According to Morse (1920) the cultivated cowpea consists of three main groups: the asparagus bear (*V. sinensis* var. *sesquipedalis*), the catjang (*V. sinensis* var. *cylindrica*) and the cowpea, each of which represents a group of varieties having much in common. The cowpea is the most important of the three.

On the history of the cowpea, Morse writes as follows:

> The large number and great diversity of cultivated varieties throughou Africa and over the southern half of Asia and the adjacent islands as well a the Mediterranean region of Europe indicate that the cowpea is of ancien cultivation for human food. It was early introduced in the Spanish settlement of the West Indies and was grown in North Carolina in 1714, probably comin

from the West Indies. Its culture in Virginia was reported about 1775 and no doubt was quite general in the United States early in the nineteenth century.

Without doubt, the cowpea is the *Phaseolus* mentioned by the old Roman writers. In Italy, the Blackeye cowpea is still called by the same name as the kidney bean, namely "fagiolo," which is the Italian equivalent of Phaseolus. In East Africa, both the wild and cultivated cowpeas are called "kunde," while in India, where the catjang is more extensively cultivated, the name "lubia," with many others is used. In America, the cowpea was first known as "callivance" and later as "Indian pea," "southern pea," "southern field pea," and "cornfield pea." The first published record of the name cowpea was in 1798 and applied apparently to a single variety.

In the southern states the cowpea is often called "pea" and the garden pea (*Pisum sativum*) is called "English pea." The term pea is, however, incorrect since the cowpea is not a pea but a bean.

The cowpea was grown for human food in ancient times, especially in Africa, Asia, and parts of the Mediterranean region of Europe. While it is grown mainly for hay, ensilage, pasturage for all kinds of stock, and as a soil-improving crop in the United States, it is used as human food in the southern states. The seeds are used as food in both the green-shell and dry conditions; while all varieties are eaten to some extent, the Blackeye and White varieties are the most popular. These two are practically the only ones sold on the market for human food. "Blackeyed peas" are more common in the stores of the South than are dry beans.

The cowpea is of special importance to the vegetable grower of the South since this is the principal soil-improving crop grown. It fits in well with the usual cropping system since it can be grown during the summer after the spring or early summer vegetable crop is harvested and before planting the winter vegetables.

Culture.—The cowpea is a warm-weather crop and is, therefore, grown mainly in the South, although it is grown with success in the southern parts of Ohio, Illinois, Indiana, and New Jersey and in parts of Michigan and other northern states. It is injured by the very lightest frost.

Cowpeas thrive on all types of well-drained soils.

When planted for forage, the seed is usually sown broadcast or in drill rows 6 to 8 inches apart, but for production of seed, planting in rows 3 feet apart, with the seeds 2 to 3 inches apart in the row, gives better results. With the row method 30 to 40 pounds of seed will be required; when sown broadcast about 90 pounds of seed to the acre will be sufficient.

When used as food, cowpeas are picked by hand or harvested with a mowing machine and threshed in the various ways mentioned for beans.

Of course, they are picked by hand when used in the green-shell state.

PEAS

Peas are grown for home use by most home gardeners and for market by market gardeners and truck growers. The pea crop is one of the important ones for canning, being exceeded in value only by tomatoes.

Statistics of Production.—The acreage, production, and value of peas grown for market in fresh condition increased enormously during the period from 1918 to 1937, as is shown in Table LV. The average price received was much lower during the last two 5-year periods, than it was during the periods 1918 to 1922 and 1923 to 1927.

Table LV.—Estimated Average Annual Acreage, Production, and Value of Green Peas Grown for Market by 5-year Periods, 1918 to 1937

Years	Acres	Yield, bu. per acre	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1918–1922	11,852	71	841	$2.07	$1,744
1923–1927	36,706	75	2,745	2.01	5,517
1928–1932	80,040	76	6,088	1.48	9,014
1933–1937	114,354	76	8,658	1.14	9,870

California accounted for approximately one-half of the total U. S. acreage of green peas grown for market in 1937. Other important producing states were Colorado, Idaho, Washington, Florida, Texas, New York, New Jersey, Virginia, North Carolina, South Carolina, and Mississippi.

The acreage of peas grown for manufacture fluctuates considerably from year to year, but the trend has been markedly upward in the 20 years, 1918 to 1937, as is shown in Table LVI. The leading states in 1937 were Wisconsin with nearly a third of the total, New York, Washington, Minnesota, Oregon, Maryland, Illinois, Michigan, and Utah in

Table LVI.—Estimated Average Annual Acreage, Production, and Value of Peas Grown for Manufacture by 5-year Periods, 1918 to 1937

Years	Acres	Yield, tons per acre	Production, tons	Price per ton	Value (000 omitted)
1918–1922	135,806	1.03	139,602	$61.07	$ 8,526
1923–1927	205,204	.96	197,066	58.58	11,544
1928–1932	223,490	.81	182,070	55.22	10,054
1933–1937	282,034	.73	204,674	50.48	10,331

the order named. These states produced over 80 per cent of the total acreage grown for manufacture that year.

History and Taxonomy.—The garden pea is of very ancient origin and its wild prototype has never been found. The pea was grown by the ancient Romans, Greeks, and some historical writers believe that it was an ancient Egyptian plant. The plant was grown at the time of Cato (149 B.C.). Hedrick (1928) states that the ancients did not distinguish carefully between peas, beans, vetches, chick peas, and lentils. This makes it difficult to determine from the written accounts what plants were being discussed.

From the evidence available it seems fairly certain that the pea *Pisum sativum* has its origin in Europe and western Asia. The garden pea was grown in middle and northern Europe in the Dark and Middle Ages. In England it was an important crop in the eleventh century.

In "Peas of New York," Hedrick divides *Pisum sativum* into six subspecies, the garden pea being listed as *P. sativum* subsp. *hortense* Asch and Graebn, and the field pea as *P. sativum* subsp. *arvense* Poir. Edible-podded peas are found in both of these subspecies, but these are not of much importance in the United States.

Climatic Requirements.—The garden pea thrives best under relatively cool weather and is grown in the South and in the warmer parts of California during the fall, winter, and early spring. The seed will germinate at relatively low temperatures, but Kotowski (1926) has shown that the time required for germination decreases as the temperature rises from 4° to 25°C. Kotowski planted seeds of the Blue Bantam variety 4 centimeters deep in quartz sand and kept them during germination at constant temperatures ranging from 4° to 30°C. The results of this experiment are given in Table LVII

At temperatures above 18°C. the per cent germination was lower than at temperatures of 8°, 11°, and 18°C. Considering both rate and percentage of germination, 18°C. was the best of the six temperatures employed in this experiment.

TABLE LVII.—GERMINATION OF PEA SEED AT DIFFERENT TEMPERATURES
(Kotowski, 1926)

Temperature, ° C.	4	8	11	18	25	30
First seedling, days after sowing	35	14	10	4	3	3
Last seedling, days after sowing	46	23	16	6	5	5
Seedlings in per cent of seed sown	84	87	88	100	82	70

Boswell (1929) has shown that as the temperature rises the yields drop off rapidly. This fact explains the reasons for low yields of late-planted peas in regions where they are planted in the spring.

Walker (1929) has shown that the yield of peas per acre in Erie County, New York, is closely correlated with the rainfall during the month of June. The correlation coefficient is $+0.89 \pm 0.01$. These data are based on average yield per acre on an Erie County farm growing a large acreage of peas from 1914 to 1925. For each 0.10-inch variation in rainfall, there was an average variation in the yield of 4.4 bushels.

The only regions in which peas are grown successfully during midsummer and late summer are those having relatively low temperatures and a good rainfall, or where irrigation is practiced. The most important regions from which peas are marketed during the hottest part of the summer are the cool, coastal sections of California, Washington, and Oregon, regions of high elevation in Colorado and other western states, and in parts of New York.

Soil Preferences.—Peas are grown on a great many kinds of soils from the light sandy loams to the heavy clays. For a very early crop, a sandy loam is desired; for large yields, where earliness is not an important factor, a well-drained clay loam or a silt loam is preferred. Good drainage is essential, for the pea plant will not thrive on soggy or water-soaked land.

The pea plant does not thrive in a highly acid soil. When the soil is more acid than pH 5.5 it is desirable to apply lime for peas. The range of desirable reaction is between pH 5.5 and about pH 6.7.

Thorough preparation is important for peas as for other vegetables. It is especially important where the seed is to be sown broadcast or planted with a grain drill since under these methods no cultivation is given the crop. Fall plowing is important for the early crop since planting is often greatly delayed when the land is plowed in the spring. When the crop is grown for the cannery, effort is made to leave the surface smooth by rolling either before or after planting, or both, as a rough, uneven surface interferes with the use of the mower in harvesting.

Fertilizers.—In some of the important pea-growing regions, peas are grown without fertilizer or with a very small application. Talbot and Tavernetti (1934) state that nitrogen and potash have not proved profitable in the Imperial Valley, but, in some instances, the addition of 200 to 300 pounds of superphosphate per acre has given increased yields. They state also that in the Salinas Valley some nitrogen should be applied in fertilizer if manure is not used and they suggest 200 to 400 pounds per acre of nitrate of soda or sulphate of ammonia. In other regions of the West, little or no fertilizer is used for peas; in most sections of the East and South commercial fertilizers are used. In most humid regions a complete fertilizer is justified and on sandy and sandy-loam soils the application should supply at least 30 pounds of nitrogen and 60 pounds each of phosphoric acid and potash to the acre for market peas.

On silt loams and clay loams, application of 20 pounds each of nitrogen and potash and 60 to 80 pounds of phosphoric acid is suggested. Some growers use less than the quantities mentioned and some use much more.

When peas are grown for canning, less fertilizer is applied than when the crop is grown for market. Peas for canning are grown very largely in rotation with general farm crops and manure is used in the rotation or sod is turned under, so that less fertilizer is needed than where cultivated crops only are grown. Furthermore, the gross returns expected from cannery peas do not justify a large expense for fertilizer.

The method of application of fertilizer is of great importance because severe injury usually results when the fertilizer is applied with the seed. Sayre and Cummings (1936) suggest that it is better not to use fertilizer at all than to apply it in contact with the seed, as is the common practice when old grain drills are used. They recommend placement in bands 2½ inches to the side and 1 inch lower than the seed. When machinery is not available for side placement, it is suggested that the fertilizer be drilled in as a separate operation before planting.

Inoculation.—Considerable difference of opinion exists regarding the importance of inoculating pea seed with nitrogen-fixing bacteria. Experiments have not given conclusive results, although it is generally recommended that inoculation be given when peas are to be planted on new land. According to Whiting, Fred, and Stevens (1925), inoculation has been profitable in Wisconsin because it has increased the yields, the protein content of the vines, the percentages of Number 1 and 2 grades of peas, and delayed maturity. In this experiment inoculation increased the yield in some cases on land that had grown peas previously. The Wisconsin workers carried on experiments on soils of varying fertility and found that inoculation was beneficial on both infertile and fertile soils. In one experiment on an acid, silt loam of low fertility, inoculation increased the yield of shelled peas 96 per cent, or a gain of about $25.29 per acre. This land had never produced peas before. Inoculation of neutral, silt loam of high fertility also gave favorable results. Wilson and Leland (1929) report similar results from experiments carried on at Ithaca, N. Y. Using artificial cultures on both limed and unlimed soils (pH 5.3) increased the yield and increased the nodules on the roots of peas.

In general, it seems advisable to inoculate the seed unless it is known that inoculation does not pay. There is evidence that it is profitable to inoculate the seed to be planted on a highly acid soil, even though peas had been grown on the area the previous year. The inoculating material is relatively inexpensive and it seems desirable to use it when there is any doubt about the soil containing the bacteria in abundance.

Planting.—The pea is relatively hardy and does not produce well in hot weather, especially if it is hot during the time of blossoming and pod setting. For these reasons early planting is important in regions where the crop is grown in summer. While the smooth-seeded type, as Alaska, will stand more cold than the wrinkled-seeded type, early planting is as important for the latter as for the former. In fact, for varieties that require a long time to reach maturity, early planting is of greater importance than it is for quick-maturing varieties.

Sayre (1928) reported results on time of planting four varieties, Alaska, Surprise, Green Admiral, and Horsford at Geneva, N. Y., that show increased yields for early planting. These results also show that it took the early-planted peas a longer time to come up and to reach blossoming and maturity than it took those planted later. Planting at weekly intervals from Apr. 9 to May 28, 1927, a spread of 49 days, gave a spread of only 20 days in the harvest with the Alaska. With the Surprise, the results were practically the same, while with the same spread in planting the Green Admiral, the harvest spread was only 16 days, and with the Horsford 13 days. The yield was markedly reduced by late planting and the reduction was greatest with the varieties (Green Admiral and Horsford) requiring the longest growing period. Boswell (1929) obtained similar results in experiments carried on for 5 years in Maryland. His results show that in a season of early high temperatures the difference in yield between early- and late-planted seed is greater than in a season of lower temperatures. In 1925, a season of early high temperatures, the average weight of peas per plant was 4.56 grams for Mar. 28 planting; 3.21 grams for Apr. 2; 2.30 for Apr. 8; 1.69 for Apr. 15; and 1.16 grams for the planting made Apr. 23.

Since late-planted peas produce a low yield in most regions, it would seem that the best method of obtaining a succession of peas is to plant early, medium, and late varieties at about the same time. Late planting is seldom profitable except in a few favorable localities where the summer temperature is relatively low.

Most pea seed is planted too deeply; this results in slow come-up and poor stands. A depth of 1 inch is sufficient in moist, heavy soil and 1½ inches on a dry, heavy soil. A covering of 1½ to 2 inches might be given in a dry, sandy-loam soil, but a depth greater than 2 inches is seldom, if ever, justified in humid regions.

Peas are planted in rows 2 to 3 feet apart or sown with a grain drill in the same manner as oats or other small grain. When sown by the latter method, no cultivation is given. At the present time a considerable part of the market crop is sown with a grain drill; all of the canning crop is so planted. With this method the quantity of seed planted varies from 3½ to 5 bushels per acre. Sayre (1928) has shown that as the rate of planting increased from 3 to 5 bushels per acre (6 bushels with some varieties) the yield of marketable peas was increased. Results of studies by the survey method made by Mills and Norton on canning peas verify the experimental results reported by Sayre. When peas are grown in rows for cultivation, the quantity of seed used varies from 1½ to 2½ bushels to the acre. Walker's data, based on a survey in Madison County, N. Y., indicate that as the quantity of seed increases up to 2½ bushels the yield goes up. The seed is one of the large items in the cost of growing the crop and, for this reason, too small a quantity is commonly planted for best results.

Cultivation.—Peas grown in the home garden and those grown for the market in some regions are planted in rows far enough apart for cultivation. When so grown, clean, shallow cultivation should be given until the vines interfere. A large part of the market crop and all of the crop grown for canning are sown so thickly that cultivation is not feasible or necessary.

Supporting the Vines.—Tall-growing varieties of peas are usually supported when grown in the home garden and to a very limited extent in commercial plantings. Sometimes trellises are used to support the vines. One method is to set stakes along the rows and to attach wires or heavy string to them, the number of strands being determined by the height the vines are expected to attain. Another method used in home gardens is to stick brush into the ground along the row. Supporting the vines makes it possible to control weeds by cultivation and renders it feasible to make several pickings, both of which tend to improve quality. When the vines are supported, the pods are exposed to view and it is fairly easy to select those pods that are in good condition for market without injurying the vines to any great extent. When they are not supported, the pods are not exposed to view and it is difficult to harvest the marketable pods without injuring the plants.

Varieties.—There are two types of garden peas based on the seed—smooth seeded and wrinkled seeded. The Alaska is the most important variety of the smooth-seeded type. The important varieties grown for market are as follows: early varieties, Mammoth-podded Extra Early, Little Marvel, Laxton Progress, Laxtonian, Thomas Laxton, Gradus, and World Record; second early varieties, Giant Stride, Midseason Giant, Asgrow 40, Stridah, Wyoming Wonder, Gilbo, and Morse Market, midseason varieties of the Stride Group; late varieties, Alderman or Dark-podded Telephone or Improved Telephone, and Telephone.

Varieties grown for canning include Alaska, a smooth-seeded, early variety; Surprise, a small, wrinkled-seeded, early variety; Canner King, Pride, Teton, Glacier, Dark-podded Thomas Laxton, and Perfection.

New and improved strains and varieties are being developed so rapidly by seedsmen and by research workers that any recommended list is soon out of date.

Diseases.—Several diseases attack the pea plant, including powdery mildew, root rots caused by several organisms, ascochyta blight, bacterial blight, Fusarium wilt, anthracnose, septoria leaf spot, mosaic, and others of minor importance. Only a few of the more important ones are discussed here.

POWDERY MILDEW.—This disease, caused by *Erysiphe polygoni*, is widely distributed and is particularly serious during warm weather. On the host plant, the fungus forms a dense mycelium which frequently covers the leaves, stems, and pods. It is recognized by the white or grayish covering on all parts of the plant.

As this disease is most destructive in warm weather, it is best to plant early or to use quick-maturing varieties. The vines and refuse should be turned under as soon as possible after harvest to prevent the production of the overwintering stage. Harter *et al.* (1934) state that dusting with sulphur has given good results in the control of this disease. The first application should be made as soon as there is any sign of the disease and another about a week or 10 days later. Sometimes as many as six or seven applications are necessary to insure a crop.

ROOT ROTS.—According to Harter *et al.*, root rots are caused by several different parasites that produce symptoms so much alike that it is not easy to distinguish them by a casual examination. They occur on the roots or on all of the underground portions of the plants and sometimes a short distance above the surface of the soil. Root decay often begins at the tips of the feeding roots and progresses upward to the main root. Sometimes the main root is the first to be affected.

Several of the organisms cause root rots of other crops, and all of them are thought to live in the soil so that crop rotation is not of much value in their control. Planting on well-drained soil, thorough preparation of the seedbed, and good fertilizer practice are recommended.

ASCOCHYTA BLIGHT.—This disease is characterized by the formation of black or purplish streaks on the stem. The leaves and pods may show spots of various sizes, either irregular in shape or more or less circular. Harter *et al.* state that the blight might be caused by any of three different parasites: *Ascochyta pisi* Lib., *Mycosphaerella pinodes* (Berk. and Blox.) Stone, and *Ascochyta Pinodella* Jones. The disease may occur in all states east of the Mississippi River, but is rarely if ever found in the semiarid, seed-producing regions of the Northwest.

Since the causal organisms are carried on the seed, it is recommended that only clean seed be used. The organisms may also live from season to season on refuse in the field; since it is not feasible to destroy all refuse, plowing it under as soon as the crop is harvested is suggested. Some varieties of peas, such as Short Admiral, Champion of England, Horal, Horsford, Perfection, and Advancer, are less susceptible to injury than others.

FUSARIUM WILT.—This disease is caused by *Fusarium* spp. When it makes its appearance in the field only a few plants show signs of disease. The lower leaves become yellow and the plants stunted. Affected leaves show a downward curling of the margins. When infection occurs while the plants are small, they may die without producing any peas; if plants are of considerable size, they may produce a few, poorly filled pods. Infection takes place from the soil through the roots and the organism follows the water conduction canals up the stem, often into the branches, thus obstructing the movement of water.

There is no cure for the wilt, but several resistant varieties have been developed. These include Alaska, Laxtons Progress, Hundredfold, Stratagem, Thomas Laxton, Alderman, Giant Stride, Stridah, and strains of several others. New resistant strains are appearing each year.

Insects.—Several species of insects attack peas, but only two are considered of sufficient importance to be discussed here. These are the pea aphis and the pea weevil.

PEA APHIS (*Macrosiphum pisi*).—The pea aphis is the only insect pest that seriously affects peas. This is one of the larger species of plant lice, pale green in color. It attacks the young vines, sucking the juices first from the growing tips, but eventually covering the entire plant. During midsummer, the lice are nearly exterminated by predaceous insects and disease, but as cool weather approaches they increase in numbers again.

Various methods of control have been attempted, including spraying and dusting with nicotine preparation, but none has been found very practicable because of the cost. Dusting with a 4 per cent nicotine-lime dust at the rate of 50 pounds to the acre has given fairly good control when applied properly. Ordinarily it is necessary to use a canvas trailer to confine the dust. Rotenone dust and rotenone spray have also been used.

PEA WEEVIL (*Bruchus Pisorum*).—The pea weevil is a serious enemy of the field and garden pea. It is now found in nearly all parts of the world, but does comparatively little damage in the colder portions of Europe and North America. The eggs are deposited on the surface of the pods. In the vicinity of Washington, D. C., a considerable number of the weevils mature and leave the seeds in the latter part of the summer, but farther north and in high altitudes the adult remains in the seed until the following spring. The weevil passes the winter in the adult stage, either in secluded spots in fields and buildings or in the pea itself. The weevil has only one generation a year and does not reproduce in dry seed.

Cleaning up the refuse in the field helps to reduce the number of beetles. Fumigation with carbon disulphide will destroy the weevils in the stored peas.

Harvesting.—Peas grown for home use and for the general market are picked by hand; this is the most expensive operation connected with the production of the crop. According to Walker (1929), the cost of picking peas in Erie County, N. Y., in 1925 averaged 40 cents per bushel and in Madison County 28 cents per bushel. The cost per acre was $35.07 in the former and $46.44 in the latter. The picking cost was 33.3 per cent of the total cost of production, excluding shipping and selling.

In picking peas by hand it is the practice of some growers to make two or three pickings, while others make only one. In the latter case the vines are pulled and all the filled pods are picked off. It costs less to pick an acre of peas by this method but the quality of the product is better and the yield higher when two or more pickings are made.

Peas for the cannery are harvested with a mowing machine. The vines are cut as near the ground as possible. They are then loaded onto wagons and hauled to a viner where the peas are shelled and separated from the vines and pods by machinery. Mowing machines are often equipped with special devices that lift the vines so that they can be cut close to the soil. These are large-fingered attachments placed on the cutting bar. Some machines are equipped with "swathers" or "windrowers" which roll the vines to the center of the swath. A hay loader may be used in loading the vines from the windrow.

The time for harvesting peas is determined largely by the appearance of the pods. These should be well filled with young, tender peas, changing in color from a dark to light green. It is the aim to harvest the peas while they are still in prime condition but without sacrificing yield. If harvested too early, the yield is light; if delayed too long, the quality is poor although the yield is heavy.

Boswell (1929) has shown that the temperature has a marked effect on the rate of ripening of peas and for this reason, when the temperature is high at harvest time, it is important that there be no delay in harvesting when the peas reach the right stage. His results indicate that there is no appreciable difference in quality or in chemical composition of peas ripening under different temperatures if the crop is harvested at the proper stage. The lower quality often obtained during hot weather is probably the result of such a rapid rate of maturing that the peas are not harvested at the best stage. Quality of peas is associated with the starch-sugar ratio. High sugar and low starch content make for high quality. During maturity there is a rapid decrease of sugar and soluble nitrogenous substances, and an increase of starch and other polysaccharides and in insoluble nitrogen compounds, mainly proteins. Sayre, Willaman, and Kertesz (1931) have shown that migration of calcium to the seed coat as the peas ripen increases the toughness of the skin. This toughness of the seed coat and firmness of the pulp are measures of maturity and can be determined by mechanical means.

Since peas deteriorate rapidly at high temperatures it is important that they be handled quickly after they are harvested. Peas for canning should be packed as soon as possible and those for market should be kept as cool as is feasible until they reach the consumer.

Grading and Packing.—Peas grown in the West for shipment to eastern markets are well graded and it is seldom that any low-grade product reaches the market from that region. A large part of the crop grown for local and near-by markets are poorly graded or not graded at all. Jamison (1934) reported studies made in New York in 1930, 1931, and 1932, in which 538 samples of peas were taken as they were brought to the loading stations. These samples averaged 72 per cent good peas, 6 per cent yellow pods, 20 per cent flat pods, and 2 per cent pods injured by insects or disease. Only 8 per cent of the shipments would fulfill the requirements of the U. S. No. 1 grade.

Some grading should be done even if no grade designation is used. The overmature, yellow pods, the flat pods, the diseased and insect-injured pods, and the trash should be removed before the peas are packed for market. In many cases careful picking would eliminate the trash and defective pods.

Peas are packed for shipment in baskets, hampers, and boxes. The round-stave bushel basket and the bushel tub baskets probably are the packages in most general use. In packing, it is important to have the container well filled so that it will not be slack when it reaches the market.

The U. S. Department of Agriculture has promulgated standards for fresh peas and these should be used wherever feasible.

Peas for canning are graded into four grades based on size of the shelled peas. The peas are run over screens that separate them into the various sizes, the smaller sizes being considered of the best quality and bringing the highest prices. Some canners buy peas on contract on the graded basis, paying the highest price for the smallest size. The sieves used for separating the sizes have mesh ranging from $^{18}/_{64}$ to $^{24}/_{64}$ inch in diameter.

Precooling and Refrigeration.—Peas that are shipped to distant markets should be kept cool if they are to reach the market in edible condition. If the peas are warm when harvested, it is desirable to precool them. This can be done by immersing in cold water or by other means; if they are washed it is important to keep them under refrigeration until they reach the destination. By placing crushed ice in the package or over the top of the load, or both, and shipping in refrigerator cars or refrigerated trucks the load can be kept cool, provided the bunkers are kept loaded with ice.

Fresh peas can be kept for 2 weeks or more in cold storage at a temperature of about 32°F. Jamison (1934) reported results of storage that show that peas stored at 32° and 40°F. were in good condition at the end of 15 and 18 days. Those stored at 32°F. were kept for another week and were in good, edible condition at the end of that time. Similar peas held at 70°F. were unfit for sale at the end of 5 days.

CHAPTER XXV

SOLANACEOUS FRUITS

TOMATO	PEPPER
EGGPLANT	HUSK TOMATO (PHYSALIS)

The solanaceous fruits, tomato, eggplant, pepper, and husk tomato all belong to the same botanical family, Solanaceae. All are tender plants grown as annuals and produced for their fruits. The methods of culture for all are similar. They are grown from seed sown in a special seedbed, usually under cover, and are often transplanted prior to setting in the garden or field. From the standpoint of both relationship and cultural requirements they are grouped together for discussion.

TOMATO

The tomato is one of the most popular vegetables as well as one of the most important. It is grown in nearly all home gardens, and by a large percentage of market gardeners and truck growers. It is produced as a forcing crop in greenhouses of the North at the same time it is being grown in the open in the South. As a canning crop it takes first rank among the vegetables.

Few products lend themselves to so great a variety of uses as the tomato. Carver (1918) gives 115 ways of preparing it for the table. It is used cooked and raw, and is made into soups, salads, conserves, pickles, catsups, sauces, and many other products. It is served baked, stewed, fried, and as a sauce on various foods.

Statistics of Production.—The tomato ranks next to the potato and the sweet potato in total value. In fact, it heads the list in value among the perishable vegetables. The average annual acreage of tomatoes grown for market in the fresh condition during the years 1933 to 1937 was nearly double the average acreage grown during the period 1918 to 1922. Total production did not keep pace with increase in acreage and total value was actually less in the period 1933 to 1937 than in the period 1918 to 1923, as shown in Table LVIII.

The figures given in Table LVIII indicate that yield per acre decreased from 1918 to 1937. The price averaged much lower during the last 10 years than during the period from 1918 to 1927. Increase in supply and lower purchasing power of the consumer probably account for this.

The leading states in acreage of tomatoes grown for market in 1937 were Texas, with 46,700 acres; Florida with 32,500 acres; California with

TABLE LVIII.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF TOMATOES GROWN FOR MARKET IN THE UNITED STATES BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield, bu. per acre	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1918–1922	98,540	145	14,297	$1.72	$24,527
1923–1927	130,570	133	17,322	2.03	35,188
1928–1932	154,540	112	17,263	1.45	25,070
1933–1937	183,890	109	20,050	1.21	24,243

24,900 acres; and New Jersey with 12,000 acres. These four states accounted for considerably over half of the acreage of tomatoes grown for market in the United States in 1937. Other important producing states are Mississippi, New York, Tennessee, South Carolina, Maryland, Indiana, and Missouri. Most of the states produce this vegetable for market, but some of them are not listed because the quantity is relatively small.

The acreage of tomatoes grown for manufacture is much greater than the acreage reported for market in the fresh condition. In Table LIX estimates of acreage, production, and value are given by 5-year periods from 1918 to 1937. The general trend of acreage has been upward, the yield per acre shows a slight trend downward, and the price per ton shows a rather marked downward trend.

TABLE LIX.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND FARM VALUE OF TOMATOES GROWN FOR MANUFACTURE BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield, tons per acre	Production, tons	Price per ton	Value (000 omitted)
1918–1922	234,206	4.51	1,057,400	$17.75	$18,768
1923–1927	283,840	4.36	1,237,920	14.60	18,079
1928–1932	315,830	4.09	1,293,000	13.55	17,521
1933–1937	396,402	4.06	1,610,660	12.33	19,693

The leading states in the acreage of tomatoes for manufacture in 1937 were Indiana with 82,600 acres; California with 80,750 acres; Maryland with 59,200 acres; New Jersey with 32,800 acres; Virginia with 25,000 acres; Ohio with 19,000 acres; and New York with 18,600 acres. Other important producing states include Missouri, Delaware, Arkansas, Pennsylvania, Illinois, Tennessee, and Utah.

History.—The tomato is a native of tropical America and is supposed to have been eaten by wild tribes of Mexico who called it tomati. The name is of South American origin and is derived from the Aztec word zitomate, or zitotomate, and is applied to the fruit of both the common tomato and that of the husk tomato. Both of these types were grown and highly prized by the natives before the discovery of America.

According to Sturtevant (1919), the earliest mention of the tomato in literature was by Matthiolus in Italy in 1554. Probably it was known in Germany, France, Belgium, and England prior to 1600. From descriptions and cuts found in old literature, it seems fairly certain that large, smooth fruits, similar to some of the varieties now grown were known long before they came into general use in America. It is probable that they were cultivated in Europe mainly for ornament and as a curiosity until about the middle of the eighteenth century. Miller (Sturtevant's notes) reports that they were used in soups in England during the latter half of the eighteenth century.

The first mention of the tomato as being grown for culinary use in America was by Jefferson in 1781. McMahon (1806) speaks of the tomato as being held in high esteem for culinary purposes in America. In 1812 tomatoes were regularly quoted in the market of New Orleans. Thorburn (Gard. Kal. 1817) gives cultural directions for growing it. It was not until about 1835 that the tomato became quite generally cultivated for culinary purposes in America and even at that time there was considerable prejudice against its use. The tomato-growing industry made rapid strides during the latter half of the nineteenth century.

Taxonomy.—The tomato belongs to the nightshade or Solanaceae family and to the genus *Lycopersicon*. The genus comprises a few species of annual, or short-lived perennial, herbaceous plants. The many branches are procumbent or partly erect. The stems are round, soft, brittle, and hairy when young, but become angular, hard, and almost woody when old. The leaves are alternate, 5 to 15 inches long, odd-pinnate, with seven to nine short-stemmed leaflets. The flowers are borne in clusters, located on the stem between the nodes. The flowers are small; corolla deeply five-cleft, yellow, the petals recurving and broadly lanceolate; calyx with five long, linear or lanceolate sepals, which are shorter than the petals at first, but increase in size as the fruits mature. The stamens are five in number and are borne in the throat of the corolla; anthers large, borne on short filaments. The fruit is a two to many-celled berry with fleshy placentae and many small kidney-shaped seeds covered with short stiff hairs.

Most authorities recognize two distinct species, *L. esculentum* and *L. pimpinellifolium*, with four or five botanical varieties under the former. Others believe that the pear and cherry tomatoes represent true species rather than botanical varieties belonging to the species, *L. esculentum.* Bailey (1924) classified tomatoes into two species, *L. pimpinellifolium* and *L. esculentum*, with the following botanical varieties under the latter:

Var. *commune:* Common tomato
Var. *grandifolium:* Large-leaved tomato
Var. *validum:* Upright tomato
Var. *cerasiforme:* Cherry tomato
Var. *pyriforme:* Pear tomato

Climatic Requirements.—The tomato is a warm-season plant and requires a relatively long season to produce profitable yields. It is tender and will not withstand a hard freeze. In regions having less than 3½ months frost-free period the tomato is not likely to be profitable. High humidity with high temperature favors the development of foliage diseases. On the other hand, hot drying winds often result in the dropping of the blossoms. The tomato plant produces large yields under irrigation in semiarid and arid regions.

Clayton (1923) found that the tomato plant grows most rapidly at soil temperatures ranging between 24° and 31°C. At 33°C. the plants grew slowly; at 35°C. they did not increase in size.

Soils.—The tomato is grown on nearly all kinds of soils from the sands to heavy clays. Where earliness is of prime consideration, as in the production of an early crop in the North, a sandy loam is considered about ideal. In regions having a short season, light soils are preferable to heavy ones, even for tomatoes grown for canning. Where large yields are most important, as in the production of the crop for canning, loams, clay loams, and silt loams are considered better than the lighter soils except in regions having a short season. Authorities are agreed that a well-drained soil is essential for high production. It is important that the soil be retentive of moisture, especially where the crop is grown throughout the main portion of the growing season.

Fertilizers and Manures.—The kinds and quantities of fertilizers and manures that may be used with profit depend on the fertility of the soil, the cropping system followed, the returns that might be expected from the crop, and the cost of the materials used. With low prices for tomatoes and high prices for manures and fertilizers, heavy applications cannot be justified. When tomatoes are grown on contract at prices of $10 or $15 a ton, less fertilizer can be justified than when the crop is grown for market at prices ranging from $40 to $100 or more per ton.

Experimental results reported by several investigators indicate that manure is of value for tomatoes, but at the present cost of manure, when purchased, heavy applications are seldom profitable. Comin and Bushnell (1928) reported results of experiments carried on for 12 years at Marietta, Ohio, in which 16 tons of manure, supplemented with 400 pounds of superphosphate, produced slightly larger yields of tomatoes than a mixture of 320 pounds of nitrate of soda, 800 pounds of superphosphate, and 100 pounds of muriate of potash. The increase in yield on the manure plots was not sufficient to compensate for the higher cost. Similar results have been reported by Work (1928), by Hartman, Work, and Wessels (1937), by Crandall and Odland (1932), and by many other workers. Manure in moderate quantities, 10 to 15 tons to the acre, might be profitable when growing the crop for market on an intensive scale. In parts of Massachusetts, where tomatoes are grown intensively on land of high value and the plants are placed close together and staked or trellised, manure is believed by the growers to be profitable. Under similar conditions in other regions, manure might be used to advantage. Under most conditions, where soil-improving crops are turned under to maintain the supply of organic matter, manure is not likely to be profitable if it has to be purchased at a price above $3 per ton.

Results of most fertilizer experiments have shown that phosphorus is of great importance on nearly all kinds of soils. Hepler and Kraybill (1925) showed that phosphorus not only increased the yield but had a marked effect on earliness in their experiments in New Hampshire. Application of any essential element would have a marked effect on yield if the soil were deficient in the particular element. If a soil is more deficient in phosphorus than in any other essential element, the crop would respond more to phosphorus than to any other element. On relatively infertile soils, a fertilizer containing nitrogen, phosphorus, and potash can be used to advantage. The proportion of these three elements and the quantity to be used depend on the fertility of the soil, the cropping system followed, and the returns that might be expected. When grown for market on sandy and sandy-loam soils with little or no manure, a fertilizer supplying from 50 to 75 pounds of nitrogen, 100 to 150 pounds of phosphoric acid, and 100 to 150 pounds of potash to the acre should give good results. On silt-loam and clay-loam soils the potash might be reduced to a 1–2–1, 1–3–1, or a 1–4–1 ratio depending on the cropping system and previous treatments. When tomatoes are grown in a rotation with cultivated crops only the 1–2–1 ratio is suggested for the heavier soils; when grown in rotation with field crops including a sod crop with manure in the rotation, a 1–3–1 or a 1–4–1 ratio is recommended. When the wide ratios are used, the application should supply 20 to 40 pounds each of nitrogen and potash and three to four times as much phosphoric acid.

The time and method of applying fertilizer are important. When heavy applications are made, it is a common practice to apply broadcast before the crop is planted. Results of experiments indicate that application of fertilizer in bands on either side of the row at the time of planting is better than broadcast application when only a relatively small quantity is used. Regardless of the method of application, most of the fertilizer should be applied before or at the time of planting. Application of available nitrogen about the time the fruit begins to set may increase the yield markedly, even where fairly liberal fertilization has been given at the time of planting. Unless the plants are vigorous and of a dark green color at the time fruit begins to set, an application of 20 to 30 pounds of nitrogen to the acre is advisable.

Tomatoes are seldom benefited by lime even when grown on a rather acid soil. Hartwell and Damon (1914) reported results that indicate little or no response to liming an acid soil in Rhode Island. Work (1928) has shown that the yield of tomatoes was decreased where 2 tons of limestone was applied annually for 3 years. Experiments in Virginia, Texas, New Jersey, West Virginia, and Missouri indicate no benefit from liming, but Magruder (1924) reports increase in yield when lime was used in connection with manure or with cover crops. In Magruder's experiments the lime might have been beneficial by making the conditions more favorable for the organisms that cause the decomposition of the organic matter in the manure and cover crops. Decrease in yield from Work's experiments might have resulted from the lime rendering some essential element unavailable.

Plant Growing.—Tomato plants are practically always started in specially prepared seedbeds several weeks prior to planting them in the field. In most sections of the United States the seed is sown in greenhouses, hotbeds, or cold frames. Cloth-covered frames are used in the milder sections of the South, and to some extent for growing plants for canning-crop tomatoes in parts of the North. In most sections of the North, the plants are started in greenhouses or hotbeds, although cold frames are used where earliness is not of prime importance. Many growers start the seedlings in greenhouses or hotbeds and transplant them to cold frames. The various methods of growing plants, described in Chap. VIII, are used in producing tomato plants.

The time for sowing the seed depends on the facilities available, the climatic conditions, and the purpose for which the crop is grown. If facilities are not available for transplanting the plants prior to setting in the field, the seed should be sown only about 6 weeks in advance of field planting. When left too long in the seedbed, the plants usually get too "leggy" due to crowding. In regions having a short growing season, the seed is usually sown 10 to 12 weeks before time for outdoor planting in order to have large plants. For a very early market crop, even in regions having a long growing season, early sowing is practiced. Many growers sow the seed very early because they believe that slow growth is desirable, but experimental results indicate that this might be overdone. Plants kept too long in the hotbed or greenhouse under ordinary methods of growing, either get too "leggy" or become too woody if the growth is checked sufficiently to hold them back. In either case the plants do not make a quick start when set out.

Tomato seed is usually planted in rows about 2 inches apart in flats, or in rows 4 to 6 inches apart in a hotbed, cold frame, or greenhouse. If the plants are not to be transplanted prior to setting in the field they should be thinned to stand an inch or two apart, preferably the latter distance, or even more when they are to remain in the seedbed for several weeks. Most market gardeners and other commercial growers in the North transplant the seedlings when they reach a height of about 2 inches, spacing them about 2 inches apart each way. The plants are often transplanted a second time when they begin to crowd; at this transplanting, they are spaced 3 by 3 or 4 by 4 inches apart each way, or else are put in pots, paper bands, veneer bands, or tin cans. Experimental results indicate that transplanting is of no particular value if the plants are given the same space without transplanting. However, transplanting once is usually necessary to economize on greenhouse or hotbed space, but very often the second transplanting may be eliminated to the benefit of the plant and result in a saving of labor as well.

Experimental results reported by Loomis (1925) indicate that transplanting once while the plants are small may be of some advantage, but that a second transplanting prior to setting the plants in the field is more likely to be injurious than beneficial. In other words, the extra expense of the second transplanting is not justified, provided sufficient space is allowed at the first transplanting. The advantages that have been claimed for transplanting have been due to increase in spacing and other factors rather than to transplanting.

The use of containers, such as pots and plant bands, for single plants seems to have some advantages over flats or ground beds. Loomis shows a marked gain in total yield and in early yield from plants grown in paper pots over those grown in flats. These plants were grown in the greenhouse until they reached the stage for setting in the field. In 1922 the gain in early yield was 63 per cent and the gain in total yield was 29.5 per cent. In 1923 the pots increased the early yield 40.1 per cent, the total yield 15.8 per cent in the case of large plants, and 27 and 17.7 per cent respectively for small plants.

Where plants are grown in ground beds instead of in flats or individual containers, a method of blocking described by De Baun (1919) is very satisfactory and is cheaper than flats or other containers. Blocking consists of cutting the soil and compost into blocks with a tool known as a blocking hoe. For this work the shank of a wide-bladed hoe is straightened out. With this tool the soil of the bed is cut into blocks, each containing one plant. The blocking should be done 10 days to 2 weeks before they are to go to the field. According to De Baun, blocking the plants has a beneficial effect on the root systems. The long roots are cut off within 3 inches of the plant. This retards the growth of the plant and new branch roots develop so that by the time the plants are set in the field the block is well filled with small feeder roots.

Tomato plants should be hardened before they are taken to the field. This is usually done by subjecting them gradually to outdoor conditions or by allowing the soil to become dry. Any method that checks growth results in hardening. Tomatoes cannot be hardened sufficiently to enable them to withstand freezing. The hardening treatment should not be too severe.

Setting Plants in the Field.—Since the tomato plant is tender, it should not be set in the field until the danger of frost is past. In localities where frosts seldom occur, plants are set in the fall and the crop is grown during the winter, but in practically all other sections of the United States they are planted in spring or early summer. For most regions early planting is important. In many sections of the South, where the growing season is long, early planting is desirable because the plants die long before fall. In all sections of the North, early planting is important because early fruit brings the highest price and, as a rule, the earlier the plants are set the larger the total yield, since the plants usually continue to bear and ripen fruit until killed by frost.

Mills and Norton (1924) found that late planting in New York resulted in decrease in yield. Their data from 292 farms in 1919 and 133 farms in 1920 are given in Table LX.

TABLE LX.—DATE OF SETTING IN THE FIELD, AND EFFECT ON YIELDS OF TOMATOES IN 1919 AND 1920

Date of setting		Number of farms		Yield per acre, tons	
1919	1920	1919	1920	1919	1920
May 10 to 24	May 15 to 27	31	40	8.9	11.69
May 25 to June 5	May 28 to June 5	191	75	9.8	11.80
June 6 to July 1	June 6 to 15	70	18	8.0	7.85

Results similar to those given in Table LX were reported by App and Waller (1921) in New Jersey. In general, the results from experiments and from studies by the survey method seem to show that it is desirable to set out tomato plants as soon as the danger of frost is over.

The spacing given the plants in the field should be determined by the richness of the soil and the method of growing. On very rich soil, greater space should be given than on a less fertile soil; if the plants are to be pruned to single stems and staked, much less space is required than when they are not to be pruned and trained. The usual distance for untrained plants is about 3½ by 4, or 4 by 4 feet on average soil, but experimental results reported by Sayre (1928) in New York, by Rosa (1922) in Missouri, and by others show that closer spacing is likely to produce larger yields. Sayre's results with the John Baer variety on a clay-loam soil at Geneva, N. Y., are given in Table LXI.

TABLE LXI.—EFFECT OF DISTANCE OF PLANTING TOMATOES ON YIELD AT GENEVA, NEW YORK

Spacing distance, feet	Plants per acre, number	Yield, 1926, tons	Yield, 1927, tons
3 × 3	4,840	26.00	18.36
3 × 4	3,630	22.02	16.72
3½ × 4	3,111	21.40	16.46
4 × 4	2,722	18.15	12.50
4 × 5	2,178	14.20	10.50

Results of experiments at Ithaca, N. Y., reported by Thompson (1934), are similar to those reported by Sayre. With plants pruned to single stems and tied to stakes, the yield increase was nearly proportional to the number of plants to the acre where the spacing was 1½ by 3, 2 by 3, and 2½ by 3 feet apart. The larger the number of plants planted per acre, the greater is the cost of production per acre due to the cost of plants and the labor of planting and caring for them. Experimental results, however, indicate that reasonably close spacing is profitable. Spacing 3½ by 4 feet for unpruned plants, and 2 by 3½ or 4 feet for plants pruned to single stems and tied to stakes is considered good for varieties like John Baer, Chalk's Jewel, and others of similar size when grown on average soils. Under some conditions greater distances may be desirable and under very intensive culture the distance may be reduced. Some growers set plants as close as 18 inches apart in the row for the single-stem system.

Cultivation.—Frequent shallow cultivation should be given as often as is necessary to control weeds. With untrained plants, cultivation should cease after the vines cover the ground, as cultivation is likely to do more harm than good when the plants have to be moved around. Experiments carried on at Ithaca, N. Y., for 6 years and on Long Island for the same number of years show that cultivation merely for the purpose of maintaining a soil mulch was of little value. It may be of value under some conditions and of no value, or even actually detrimental, under others as explained in Chap. X. Deep cultivation is nearly always injurious due to destruction of roots by the cultivator and to bringing moist soil to the surface. All the roots shown in Fig. 59 would have been destroyed by cultivating over 2 inches deep.

Fruit Setting.—The formation of the flower bud takes place under a wide range of conditions, but fruit setting is limited to a somewhat narrow range. Abscission may take place at any time during or after the opening of the flower, resulting in the dropping of the blossoms. This dropping of the flowers may result from faulty nutrition, from unfavorable weather conditions, or from injury by disease or insects. Kraus and Kraybill (1918) have shown that the internal condition, as affected by environmental factors, has a marked effect on fruit setting. They showed that when nitrogen is deficient in the soil the plants are stunted and do not set fruit. Such plants have a high carbohydrate and low nitrogen content. When the soil contains a fairly abundant supply of nitrogen and other conditions are favorable, the plants make good growth, have a moderate content of both carbohydrates and nitrogen, and set fruit freely. When nitrogen is abundant and other conditions are favorable for growth, vegetation is vigorous, the plants are high in nitrogen and low in carbohydrates, and are unfruitful.

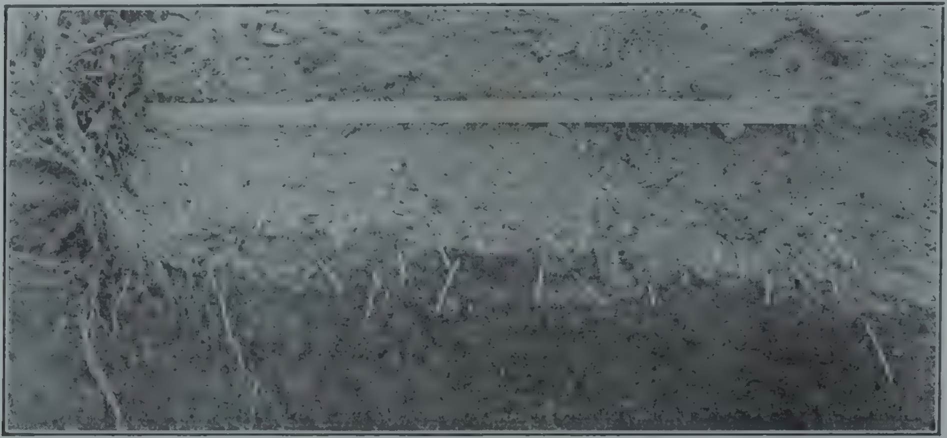

FIG. 59.—Roots of tomato plants uncovered by washing off the surface soil to the depth of 2 inches. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Fruit setting is associated with moderate vegetative growth and with a balance between the nitrogen and carbohydrate supplies in the plant. When conditions are such that vegetative growth is rapid, carbohydrates are used in new tissue formation and in respiration so that the concentration of carbohydrates remains low and no fruit is set, although blossoms are produced abundantly. Bud formation may not take place under extreme conditions of high nitrogen and low carbohydrates. If the conditions are such that little growth takes place, the carbohydrates are not used in growth but accumulate in the plant resulting in high concentration of the products of photosynthesis and the dropping of the blossom. The results of studies made by Kraus and Kraybill, by Work (1924), by Nightingale (1927), and by Nightingale, Schermerhorn, and Robbins (1928) indicate that fruit setting depends on the accumulation of a considerable surplus of carbohydrates above the current needs of the plant for vegetative extension. The concentration of carbohydrates in the plant is a resultant of the balance between synthesis and utilization in new tissue formation and in respiration. Work has shown that fruit setting is not dependent on any definite mathematical ratio of carbohydrates to nitrogen. He found that a nitrogen content of 0.3 to 0.4 per cent in the leaves was associated with vigorous vegetative growth and heavy fruiting; a content between 0.2 and 0.3 per cent with intermediate performance; and less than 0.2 per cent with a check in both vegetative growth and fruiting. Work suggests that the concentration of carbohydrates in the plant is the resultant of the balance between the processes of manufacture and the many processes of use.

Nightingale and Nightingale, Schermerhorn, and Robbins have shown that the length of daily illumination, along with varying nitrate supply, markedly affect the reproductive activity. Plants grown under a 7-hour day with nitrate in the nutrient solution were highly vegetative and unfruitful, while those grown with the same nutrient solution under a 14-hour day set fruit abundantly. With a short day and no nitrate, flowers set abundantly but no fruit, while with the long day and no nitrate neither flowers nor fruit set. Watts (1931) showed that temperature has an effect somewhat similar to that of length of photoperiod. Increasing the temperature from 60°F. to 75°F. produced results similar to those obtained by increasing the length of photoperiod. Results of the various studies mentioned indicate that more nitrogen can be utilized to advantage where the crop is grown under a long day and at relatively high growing temperatures than where the crop is grown under the shorter days of winter and at relatively low temperatures.

Flowers may fail to set fruit regardless of condition of nutrition of the plant. Flowers may drop before, during, or shortly after anthesis. Radspinner (1922) and Smith (1932) have reported dropping of blossoms in Oklahoma during periods of hot dry weather. Smith states that the drop is greatly increased by hot dry winds and low humidity, and that there is a lag of approximately 3 days between the time that temperature exerts an effect and the time that the effect becomes visible. During periods of high temperature and low humidity, the styles elongate abnormally even before anthesis, and flowers with elongated styles seldom develop normally and set fruit. Radspinner found direct relation between the relative humidity and blossom drop and concluded that environmental conditions conducive to rapid transpiration resulted in a water deficit of the plant which caused the development of the abscission layer.

Effect of Fruit on Vegetative Growth.—Murneek (1926) has shown that vegetative growth is regulated or controlled by the fruit. In his experiments this control was determined (1) by the number of fruits on the plant and their proximity to the growing points and (2) by the relative quantity of the available nitrogen supply. He found that restriction of nitrogen in the soil or of the stored nitrogen in the plant tends to retard development, and that this retardation is in direct proportion to the quantity of fruit present. The fruit seems to be able to monopolize practically all of the elaborated nitrogen, thus causing a shortage in the strictly vegetative parts of the plant. The plane of nutrition of the plant determines the number of fruits a tomato plant can develop, but regardless of the nutrient and moisture supply the fruit eventually checks or stops vegetative growth. One fruit may stop growth of a plant in a very low plane of nutrition. Removal of the fruit usually results in renewal of vegetative growth and the setting of more fruit, thus we have what may be called waves of fruit setting.

Although the developing fruits retard vegetative growth, fertilization, or the union of the gametes, stimulates vegetative growth, according to Murneek (1926). This stimulation seems to affect the whole plant as well as the tissues surrounding the embryos. In Murneek's studies, plants from which the flowers were removed prior to fertilization made less growth than did those whose fruits were removed soon after they were set.

Pruning and Training.—The practice of pruning and training tomatoes is generally followed in some sections of the United States, especially in some of the important producing regions of the South and in a few areas in the North. Various methods of pruning and training are followed, but pruning to a single stem and tying to a stake is the most common (Fig. 60). In this system all the shoots that grow in the axils of the leaves are removed while they are small. The plants are tied to stakes with soft twine looped around the stake and tied under a leaf stem on the side of the plant opposite the stake. The twine should not be tied around the plant in such a way that it restricts growth or cuts into the stem. Usually the plants are trimmed about once every week or 10 days. Some growers pinch out the top of the plant when it reaches the top of the stake. With 2-stem and 3-stem training, the desired number of shoots is selected and all others are kept pinched out. Each stem must be tied as in the single-stem system.

The stakes are usually 1 by 1 inch or 1¼ by 1¼ inches square; they may be made out of saplings cut from the woods in which case they should be about 1½ inches in diameter. They are usually 5 to 6 feet tall and are driven into the ground 12 to 18 inches and a few inches from the plant. Tomato plants are sometimes tied to wires attached to posts set in the ground or to heavy stakes driven into the soil to the proper depth.

The advantages claimed for pruning and training are (1) earlier ripening, (2) larger fruits, (3) less disease injury, (4) larger yields, (5) cleaner fruit, (6) more convenient harvesting, and (7) greater convenience for spraying. The disadvantages usually mentioned are (1) greater amount of labor and expense, (2) less total yield, (3) greater loss from blossom-end rot, (4) more sunburn on the fruit, (5) greater amount of cracking.

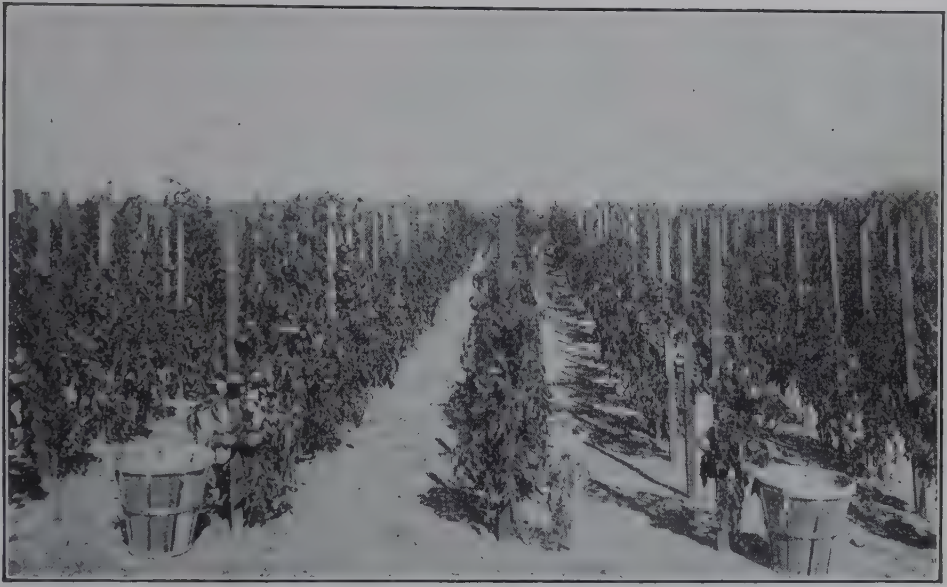

Fig. 60.—Tomato plants pruned to single stems and tied to stakes. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Experimental results on pruning and training of tomato plants are conflicting; this might be expected because the experiments were conducted under many different conditions. There was a great variation in the spacings and in some cases the experiments were of too short duration and insufficient replications to give reliable results. From the results of a large number of experiments, it seems safe to conclude that the total yield per acre is likely to be less from pruned plants than from unpruned plants, unless the pruned ones are set considerably closer than the unpruned. In nearly all the experiments, plants pruned to a single stem produced a lower yield per plant than unpruned plants. In experiments covering a period of 6 years at Ithaca, N. Y., reported by Thompson (1934), the average yield per plant was 3.77 pounds for those planted 2 by 3 feet and pruned to one stem; 7.15 pounds for unpruned plants set 3 by 4 feet; and 8.64 pounds for unpruned plants set 4 by 4 feet apart. Results reported by Bailey and Corbett (1892) in New York, Lloyd and Brooks (1910) in Illinois, Wicks (1913) in Idaho, Olney (1918) in Kentucky, Rosa (1922) in Missouri, Magruder (1924) in Ohio, and Watts (1933) in Arkansas show larger yields per plant on unpruned plants than on those pruned. Stucky (1915) in Georgia and Whipple and Schermerhorn (1915) in Montana reported results in which the yield per plant was greater for pruned plants than for unpruned ones. In Georgia foliage diseases were severe and in Montana the growing season was so short that only a small crop was produced.

In some of the experiments mentioned, the pruned and unpruned plants were given the same space while in others the pruned plants were given less space than the unpruned ones. The evidence indicates that with equal spacing, the unpruned plants might be expected to produce larger yields than the pruned, except in regions where foliage diseases are very severe and the plants die early or where the growing season is extremely short.

Pruning tomato plants has little effect on hastening ripening, but the larger number of pruned plants usually set to the acre generally results in a larger yield per acre for the first 2 or 3 weeks. In general, the larger the number of plants, the greater is the number of first clusters of fruit and hence the greater the early yield. In most of the experiments there was little or no increase in early yield per acre from pruning and training, unless the pruned plants were set closer together than the unpruned ones. Watts obtained a decrease in early yield by pruning to a single stem in one location in Arkansas and an increase in another location in the same state; in both locations the pruned and unpruned plants were given the same spacing. Rosa obtained larger early yields per acre from unpruned, untrained plants set 3 by 3 feet apart than from pruned, trained plants set 2 by 3 feet apart.

Blossom-end rot is usually more severe on pruned, trained plants than on the unpruned, untrained ones. This was shown in the results obtained by Stuckey and by Olney. Similar results (unpublished) have been obtained by the writer at Ithaca, N. Y. The fact that blossom-end rot is nearly always severe during dry weather and is worse on pruned, trained plants than on unpruned ones indicates that the pruning and training allow more moisture to escape from the surface of the soil, or else the pruned plants cannot get the moisture as well as the unpruned plants. Results of studies by Thompson (1927) indicate that both of these factors are probably involved. Moisture determinations show greater loss of water from the soil growing pruned plants than from the soil growing unpruned ones, and root studies show a smaller and more restricted root system on the pruned plants. The transpiration rate is probably much higher from the pruned, trained plants. The unpruned, untrained plants act as a mulch on the soil, restricting the movement of the air and shading the surface so that less moisture is lost by evaporation.

Training tomatoes on stakes, or on other supports has a decided advantage in harvesting and in keeping the fruit clean, and, in some cases, results in less rotting, particularly by soft rots. On the other hand, tomatoes grown on pruned, trained plants are more subject to cracking around the stem end and to sunscald on the side exposed to the midday sun.

The main disadvantage of the pruning and training is the increase in cost of production. With any practicable system of single-stem training, at least twice as many plants are required as in the ordinary method of growing unpruned plants. At 2 by 4 feet 5,440 plants are required per acre, while at 4 by 4 feet only 2,720 are needed. The extra expense in growing the plants and setting them in the field, the cost of stakes and twine, and the cost of labor required to prune and tie the plants every week or 10 days for several weeks must be offset by the increase in returns for pruning and training to be profitable. The cost of pruning and training varies widely due to differences in plant-growing methods, to cost of stakes and labor.

Under some conditions the practice of pruning and training apparently is profitable. Where foliage diseases are very severe and where the early part of the crop brings a relatively high price, pruning and training are most likely to be profitable. In some intensive, market-garden areas where land values are high, tomatoes are grown successfully and profitably under the pruning-and-training method. Under such conditions plants are set close together; the soil is heavily fertilized; the plants are given the best of care; in many cases the land is irrigated; and in some cases a mulch is used.

Varieties.—A large number of varieties of tomatoes are in existence, but not so many as is indicated by the names found in the seed catalogs. In 1902, American seedsmen listed 327 so-called varieties, but undoubtedly many of the names were synonyms. Only a small percentage of the varieties grown in the United States at the present time are of much importance. Ten to fifteen varieties constitute the bulk of the crop grown for home use, for market, and for canning.

In choosing varieties of tomatoes the following points should be considered: (1) the purpose for which it is grown, whether for home use, for market, or for manufacture; (2) the length of the growing season; (3) the yield; and (4) the susceptibility to disease. When the crop is grown for home use only, the preference of the family should be considered as far as the quality, type, and color of fruit are concerned. When grown for the general market the preferences of the buyers should be considered. Some markets seem to prefer red-skinned fruits, while others prefer those with pink skin. Earliness is usually an important consideration in growing for the market, therefore, some early-ripening variety should be grown. For canning the following qualities are important: (1) high yield, (2) good color (bright red), (3) smooth surface, (4) small core, and (5) fairly solid flesh.

Boswell *et al.* (1933) listed nine varieties of tomatoes as the principal ones grown in the United States: Earliana, Bonny Best, Gulf State Market, Globe, Marglobe, Early Detroit, Greater Baltimore, Stone, and Santa Clara. These varieties have been described and characterized by Boswell *et al.* There are many strains of each of these, some of which are considered as distinct varieties by some seedsmen and some growers and are known under names other than those listed above. For example, the Bonny Best group includes three well-known names, Bonny Best, John Baer, and Chalk Jewel. There are many stocks and strains of the well-known varieties and some of them are given varietal names. Many new varieties have been developed during recent years to meet some specific need or condition, such as resistance to disease, early maturity, or some other desirable quality. Some of the newer varieties that are becoming well known are Pritchard, Break O'Day, Rutgers, and Scarlet Dawn. Many other varieties are grown but most of them are limited to special areas.

The most important early varieties are Earliana and Bonny Best; other early varieties such as Pritchard, Break O'Day, and some others are popular in some regions. Some strains of the Earliana are the earliest available, but there are late strains of this variety that are no earlier than early strains of Bonny Best. Improved strains of Earliana, that are of better market quality than the old strains, have been developed in recent years. The Bonny Best is the most popular early variety in many regions, because of its smooth fruits of desirable size and good quality.

Of the second early varieties the Marglobe, Gulf State Market, Globe, and Early Detroit are perhaps the most important. Rutgers, a variety of high quality, developed by the New Jersey Experiment Station is becoming popular in many regions. The Marglobe has become popular in many regions because it is a good tomato resistant to Fusarium wilt and nailhead rust.

The important late varieties of tomatoes are Greater Baltimore, Stone, and Santa Clara, all three being important canning varieties.

The Santa Clara is by far the most important variety grown in California and is grown also in other western states.

In addition to the varieties commonly grown in the field are the forcing varieties, such as Comet, Michigan State Forcing, and many others grown primarily in greenhouses. The Comet is grown to some extent as staked or trellised tomatoes.

Since the old varieties are being improved and new varieties are introduced each year, descriptions of present varieties are of little value, hence are not given here.

Diseases.—The tomato is subject to the attacks of a great many diseases affecting all parts of the plants—roots, stems, leaves, and fruits. Chupp (1925) lists over 30 diseases of this crop, but not all of them are found in any one region. Probably the most important are fusarium wilt, bacterial wilt, leaf spot, late blight, macrosporium blight (nailhead spot of the fruit), bacterial canker, root knot, mosaic, western yellow blight, blossom-end rot, and streak.

FUSARIUM WILT (*Fusarium lycopersici*).—This disease is very widespread and is especially serious in the Middle Atlantic, Gulf coast, and lower Mississippi Valley states. It is characterized in its early stage by a wilting of the plant and an upward and inward rolling of the leaves. The leaves turn yellow and slowly die, the lower ones first but finally the upper ones also. A cross section of an infected stem shows a dark-brown discoloration between the pith and bark. This discoloration of the woody layer distinguishes this disease from bacterial wilt.

Since the fungus causing wilt can live in the soil for several years, control measures must consist of soil treatment, or the use of wilt-resistant strains or varieties. Soil treatment is not practicable except in the greenhouse where thorough sterilization will control the disease. Several wilt-resistant strains and varieties have been developed during recent years, the most important one being Marglobe. This variety was developed by F. J. Pritchard of the U. S. Department of Agriculture. It is a hybrid between Marvel and Livingston's Globe and is a good commercial variety. Other resistant strains or varieties are Pritchard, Break O'Day, Glovel, Illinois Pride, Early Baltimore, and several others that are adapted to special areas or grown for special purpose as forcing in greenhouses. The Marglobe is the most important of the wilt-resistant varieties and is now grown on a large scale in regions where the Fusarium wilt is serious.

BACTERIAL WILT (*Bacillus solanacearum*).—Bacterial wilt or bacterial blight is often very serious in the South and is also present in many sections of the North, but usually not very destructive. Plants affected with this disease usually wilt more rapidly than those attacked by the Fusarium wilt. Affected plants remain green for a while after they are infected, then suddenly wilt. The discoloration of the stem is black rather than brown. When cut, the stem exudes a dirty milky slime. The bacteria causing the blight can enter the plant only through a wound and are usually introduced by insects. They may also be carried from diseased to healthy plants by pruning knives and cultivating tools.

Sherbakoff (1918) suggests the following control measures:

> Make the seedbed on a soil not previously used for growing tomatoes or other crops suceptible to the disease, or sterilize the seedbed soil with steam or formalin.
>
> Rotate crops in the field so that tomatoes or crops related to them will not be planted on the same soil more often than once in several years. While this rule is generally a good one to follow, experienced tomato growers say its observance is imperative following a crop once affected with the blight.
>
> The tomato field should be frequently inspected for blight and every diseased plant removed and destroyed.
>
> Keep in check the various insects that may be working on the plants.
>
> Do not plant tomatoes in a soil infested with root-knot nematodes.
>
> Do not injure the plant roots unnecessarily in transplanting.

The bacterium causing the bacterial wilt of tomato also attacks potatoes and eggplants.

LEAF SPOT (*Septoria lycopersici*).—This disease, also known as blight, is widely distributed east of the Rocky Mountains and is destructive in the Middle Atlantic and Middle Western states. It is not of great importance in the cooler portions of the North or in the South Atlantic and Gulf coast states.

The disease appears on the leaves as water-soaked spots which finally turn brown. A yellowing of the leaf takes place and the edges begin to roll and the leaf finally dries up and drops off. The older leaves die first but the disease works outward or upward to new leaves until the plants are often almost completely defoliated before half of the crop is matured. Leaf spot is more serious during wet weather than in dry.

Pritchard and Porte (1924) suggest several control measures, including the use of large plants, the turning under of all refuse, destruction of horse nettle, ground cherry, jimson weed, and nightshade, the burning of dead weeds and grass along fence rows and in other waste places, and spraying with Bordeaux or other copper-spray mixtures. They state that the effects of leaf-spot epidemics can be largely avoided by setting out large, stocky, well-hardened plants early. The fungus has a high minimum sporulation temperature—59°F. Spraying with Bordeaux mixture or other copper-spray mixtures will give control if thoroughly done, but spraying is not always profitable. In the cooler regions the disease is not usually serious enough to require remedial measures.

Early Blight (*Macrosporium solani*).—The fungus causing the early blight of tomatoes is the same one that causes early blight of potatoes. According to McWhorter (1927) there are two distinct cycles of the early-blight disease—the long cycle (*A*) and the short cycle (*B*).

> *Cycle A*.—The early blight fungus (*Macrosporium solani*) attacks the seedlings in the plant bed. It may be introduced in or on the seed or already be present in the soil. Many of the seeds fail to germinate, others germinate and damp-off (seedling-blight). Of those that reach the second or third leaf stage many have lesions developing at the ground line (foot rot). If foot-rot plants are set into field the organism may readily pass to the stem (stem blight) and later to the leaf (Macrosporium leaf blight). Spores form on the leaves and stems and thereby furnish inoculum for the other stages in the following order: Lesions on the calyx portion (blossom blight); lesions on the fruit (black rot); this is followed by dropping of the fruit. Seed infection is associated with the black-rot stage.
>
> *Cycle B*.—The short cycle is initiated by primary leaf-lesions that result from contact of lower leaves with contaminated field soil. This is followed by stem infection, then blossom infection, then fruit infection, then fruit drop.

The rot on the fruit, described and illustrated by McWhorter, is different from the nailhead disease of tomato which is caused by a species of Macrosporium. "The black-rot lesions appear as intensely black oval areas on the surface of the fruit. As the lesions age, black feltlike spore masses may form on portions of the spots."

The same control measures recommended for the Septoria leaf spot are suggested for the early blight. Only seed from disease-free fruits should be planted and any plants showing disease in the seedbed should be discarded.

Nailhead Spot.—This disease is caused by a species of Macrosporium, probably *M. tomato*, and causes serious losses to tomato growers in Florida. According to Ramsey and Bailey (1929) the nailhead-spot disease is characterized by small, circular, slightly depressed, grayish-brown to brown, superficial spots on the fruits. In the early stages the spots are flat and tan in color, but as they enlarge the margins become more definite dark brown to almost black, and the centers change to gray or grayish-brown and are definitely sunken. The spots develop on the fruit in the field, in the packing house, and during transit and marketing. Most serious infection takes place on the smaller fruits, particularly on the less mature fruit. The rate of development decreases as the fruit matures. The spots are small, rarely exceeding 6 millimeters in diameter.

Mosaic.—Plants affected with mosaic show abnormal leaf development, variegated mottling of dark and light green areas predominating. At times diseased plants have fernlike leaves. In severe cases production is greatly reduced, but slightly affected plants often yield normal crops This disease is often very serious on greenhouse tomatoes. Mosaic i highly infectious and spreads rapidly. Gardner and Kendrick (1922 state that the same disease affects tobacco, pepper, petunia, and a numbe of related plants including weeds:

> The disease is spread largely by insects, especially by plant lice, and certai cultural operations, such as pruning and transplanting.

Gardner and Kendrick suggest the following control measures fo mosaic:

1. Do not use tomato transplants from plant beds in which mosaic is present. Guard against spread during transplanting.
2. Eradicate all horse nettles, ground cherries in and near greenhouses plant beds, and tomato fields early in the season.
3. Keep tomato fields free of all solanaceous weeds, annual or perennial.
4. Keep plant beds free of all weeds and tomatoes during the summer.
5. Keep greenhouses free of volunteer tobacco and tomato plants and a related weeds.
6. Control insect carriers by spraying or fumigation.

LATE BLIGHT (*Phytopthora infestans*).—This disease is due to the sam fungus causing late blight of potatoes. It appears comparativel late in the season and shows on the plants as black, water-soaked spot on the older leaves and stems. The spots enlarge and increase in number, killing the leaves and rotting the stem. In severe attacks the plan rapidly turns black and dies. On the fruit, the spots are sunken an discolored, usually at the stem end.

Spraying with Bordeaux mixture has given good results in Virgini and elsewhere.

BLOSSOM-END ROT.—This disease affects the fruit only and, a indicated by the name, occurs at the blossom end. The first appearance is as a small yellowish spot around the dried blossom. The spo gradually enlarges and takes on a dark brown or black color. Th affected tissue shrinks, resulting in a more or less sunken spot. N causal organism has been found and authorities are agreed that it is physiological disease due to certain conditions adverse to the norma growth of the plant. Irregular water supply, especially a sudden chec in it is the chief cause of the disease. It nearly always appears in a dr season.

Any cultural practice that helps to conserve soil moisture aids in th control of blossom-end rot. Irrigation will completely control it, i properly used. Results secured by Stuckey (1916) in Georgia seem t indicate that resistance and susceptibility to blossom-end rot are transmitted from parent to progeny.

Pruning and training tomatoes apparently increase blossom-end rot as was shown in experiments in Georgia, in Kentucky, and in New York. This the writer believes to be due to lower soil moisture under the pruning and training, and possibly to the smaller root system of pruned, trained plants as explained in a previous paragraph.

BACTERIAL SPOT.—This disease is caused by *Phytomonas vesicatoria* and affects both the leaves and fruits, the greatest damage being caused by the spotting of the fruit. The spots on the leaves appear as water-soaked areas which enlarge and the centers become black and sunken on the lower side. Infection of the young leaves may cause them to turn yellow and drop. Lesions also appear on the petiole and stem. The lesions resemble those of the septoria leaf spot. The lesions on the fruits appear as small, black, raised spots surrounded by a narrow water-soaked zone. The spots enlarge until they reach a diameter of 6 to 8 millimeters and extend some distance into the fruit. As the tissue disintegrates, the raised spots sink until they become cavities bordered by the broken epidermis.

The use of clean seed and the growing of plants in soil that has not grown tomatoes for at least 3 years are control measures recommended. Gardner and Kendrick (1921) recommend treating seed with a solution of corrosive sublimate at a strength of 1 to 3,000 for 5 minutes and then washing for 10 to 15 minutes in running water.

YELLOWS OR WESTERN YELLOW BLIGHT.—This disease, which has been known for some time as western yellow blight, was thought to be caused by Fusarium. It is now recognized as a virus disease. Shapovalov (1928) stated that the disease is caused by a virus closely related to curly top of sugar beets and is transmitted by beet leaf hoppers. Later, Shopovalov and Beecher (1930) and others showed rather con-lusively that it is spread by the beet leaf hopper. Severin (1928) has hown that tomatoes inoculated with the curly-top virus from beets y means of infected leaf hoppers developed typical symptoms of yellows.

No control measures have been developed for this disease, but studies re being undertaken to develop types that are resistant to the disease. esley (1926) reported results of studies on varietal resistance, but to ate no resistant commercial variety is available.

BACTERIAL CANKER.—This disease is also known as Grand Rapids isease and the causal organism is a bacterium *Phytomonas Michi-anense.* Until recently it was known only in the North, but now it as appeared in virulent form in the South and West. Plants attacked y this disease look somewhat like those infected with Fusarium wilt. nfected stems become stunted and the disease progresses from the lower aves upward. According to Bryan (1928 and 1930) the stems and tioles remain turgid, while the leaflets wilt and turn brown and dry.

This is followed by pale yellow streaks on the stem, which may later crack open. In severe cases the whole plant dies. The measures recommended for control are: (1) selecting seed only from healthy plants, (2) plowing under or destroying all refuse, (3) rotating crops, so that tomatoes are grown on the same area only once in 3 or 4 years, and (4) treating seed with corrosive sublimate solution as recommended for bacterial spot.

Root Knot.—This disease, caused by a nematode (*Heterodera radicicola*) is very destructive to tomatoes in the South and in greenhouses in the North. It attacks practically all vegetables. This disease has been described under "Cabbage" (p. 281).

Tomato Hornworms.—Tomato hornworms are large green worms sometimes called tomato worms or tobacco worms as they feed about equally well on both plants. They are the larvae of large sphinx moths of two species, similar in habits. The worms devour the foliage very rapidly. One worm will strip a large tomato plant. Hand picking is the most economical and the best method of control. The worms can be killed by dusting the plants with a ¾ of 1 per cent rotenone dust or with 20 per cent calcium arsenate dust; it is not advisable to use arsenicals on the plants after the fruits set.

Tomato Fruitworm.—This worm is a very serious pest in many sections of the South, where it eats into the green fruit. It is the same insect as the bollworm of cotton and the corn earworm. Since it prefers sweet corn to tomatoes, the latter may be protected by planting a row of sweet corn here and there in the tomato field.

Harvesting.—The stage of maturity at which tomatoes are picked depends upon the purpose for which they are grown and the distance they are to be transported. Several stages are recognized, including immature green, mature green, turning, half ripe or pink, and ripe or red ripe. Fruits picked in the immature green stage may not have reached full size and are usually tough, leathery, and of poor color when ripened artificially. Mature green fruits are full grown but have not begun to turn pink; the seed cavities are filled with a jellylike material; the color has begun to change to a whitish green, especially at the blossom end. Fruits picked at this stage of maturity will develop good color when ripened under favorable conditions. Fruits classed as "turning" show some pink, especially on the blossom end, but most of the surface is still green. Half ripe or pink fruits show some pink color over most or all of the surface, varying from light pink to nearly red in color. Ripe or red ripe fruits are those that have developed full color for the variety but are usually firm.

Tomatoes intended for use as ripe fruit should never be picked in a less mature stage than mature green and where feasible they should be allowed to reach the turning stage, since it is difficult for the pickers to determine the mature green stage. Most tomatoes picked before they reach the turning stage are selected on the basis of size alone; Sando (1920) has shown that size is no criterion of maturity. He has shown also that tomatoes picked in the immature green stage never develop the quality of vine-ripened fruit, or fruit picked in the turning stage. His analyses show that during development and maturation of the fruit there is an increase of moisture and of sugars. Fruit of the Livingstone Globe variety at 14 days of age contained 25.83 per cent sugars on dry-weight basis and at 56 days, when the fruit was turning, the sugar content was 46.03 per cent. When ripe, the sugar content was 48.32 per cent. Starch decreased during maturation from 15.84 to 2.65 per cent, the most marked decrease occurring during the period of transition from green to red.

It is generally conceded that tomatoes shipped to northern markets from the South are inferior in flavor and palatability to vine-ripened fruit. Analyses of green, turning, and vine-ripened fruit reported by Sando show that green fruit ripened at room temperature is lower in sugar and higher in acid than vine-ripened fruit. The ratio (sugar ÷ acid) was 1:5.54 in the artificially ripened fruit and 1:6.34 in the vine-ripened fruit. Tomatoes picked when they were turning ripened better than those that were picked green. The composition of turning tomatoes compared more favorably with vine-ripened fruit. The sugar-acid ratio was 1:6.78 in the former compared with 1:6.34 in the latter. Sando states that differences in the chemical composition between vine-ripened fruit and commercially picked green tomatoes, ripened in the laboratory and exposed to air and light, are not sufficient to account for the marked differences in flavor and palatability between commercially ripened fruit and normal fruit. He thought that lack of ventilation during commercial ripening might be responsible for the difference. He analyzed tomatoes which were ripened in a nonventilated chamber and compared the results with those obtained with wrapped fruit.

A comparison of composition of fruits ripened in various ways is shown in Table LXII.

TABLE LXII.—COMPOSITION OF TOMATOES RIPENED UNDER DIFFERENT CONDITIONS
(Sando, 1920)

Condition of ripening	Acid, per cent	Sugar, per cent	Ratio (sugar ÷ acid)
In box without ventilation	1.104	2.325	2.11
Wrapped in paper	0.850	2.462	3.01
Unwrapped	0.475	2.631	5.54
Ripened on the plant	0.420	2.667	6.34

A glance at the data in Table LXII will show that the percentage of acid is much higher in fruits ripened without ventilation than in those ripened where the oxygen supply is ample. The ratio of sugar to acid is low in tomatoes ripened without ventilation. The quality of fruit of the Globe variety picked green and ripened in air compares favorably with vine-ripened fruit. However, Rosa (1925) found that fruit of Earliana, Stone, and Globe varieties ripened artificially has only slightly more sugar than green fruit and much less than vine-ripened fruit. With the Globe variety, however, the sugar content of artificially ripened fruit more nearly approached that of vine-ripened fruit than did the fruit of the other two varieties.

Most of the fruit grown for long-distance shipment to market is picked in the mature green stage. Sando showed that "turning" fruit can be held for 15 days at 50° to 55°F., and 5 days or longer at approximately 75°F. and this stage is preferable to the green stage. Fruit grown for near-by markets is picked usually in the half-ripe or ripe stage, although some growers pick in the mature green or turning stage and ripen the fruit artificially or ship as "green wraps." Tomatoes for canning or for juice are allowed to reach the ripe or red ripe stage before picking, since they are prepared soon after they are picked and since good color is essential in the prepared product.

Artificial Ripening.—At the present time most of the fruit is picked in the green mature stage and is ripened artificially by being placed in ripening rooms where the temperature is maintained at 70° to 75°F. At intervals of 2 or 3 days the fruits are sorted and those showing sufficient color are removed and sold. Hibbard (1930), Work (1928), Rosa (1925 and 1926), and others have shown that the use of ethylene gas hastens the ripening of tomato fruits. The concentration of ethylene gas usually recommended is 1 part of ethylene gas to 1,000 parts of air, but Rosa shows that concentrations of from 1:4,000 to 1:5,000 were about equally effective. The gas needs to be renewed at intervals in order to maintain the proper concentration. The gas causes the red pigment to develop rapidly and the other ripening processes to be accelerated. According to Rosa, fruit ripened with ethylene gas has a higher sugar content than that ripened in air.

Ethylene ripening is being used commercially with very satisfactory results. The fruits are picked at the mature green, at the turning, or at the half ripe stages and ripened artificially, even where it is feasible to allow them to ripen on the vines. When tomatoes are picked at the stages of maturity mentioned, there is likely to be less cracking of the fruits, less sunburn and, when ripened artificially, the color develops more uniformly than when they are vine ripened.

Grading.—The grading of tomatoes for market has been practiced to some extent for a long time, but prior to 1917, when the U. S. Department of Agriculture began studies of grades, no concerted effort had been made to formulate grade standards. At present the Department has grade specifications for market and canning tomatoes. These specifications are frequently revised, hence are not given here. In grading for market, it is important to separate the fruits according to size as well as to eliminate all fruits that are injured.

Gaylord (1928) has shown that buying tomatoes on the graded basis for canning is of advantage to the canner and to the good growers. On the flat-rate basis all growers get the same price, while when tomatoes are bought on the graded basis the good grower gets the benefit of producing a high-quality product and in using care in harvesting. According to Gaylord the grading system increased the percentage of Number 1 tomatoes, decreased the culls, and enabled the canner to buy his product more economically. The results of the experiments in Indiana reported by Gaylord show that fewer green, rotten, and defective tomatoes, and a larger percentage of red ripe, sound fruits can be obtained by buying on the graded basis than in any other.

Packing and Packages.—Various methods of packing tomatoes are in use. For local markets little attention is given to method of packing or to the kind of package used. The top layer of fruit is often placed by hand and too often this layer of fruit is much better than the reminder in the package.

When packed for long-distance shipment, the fruits usually are placed by hand in layers with the top layer in rows; in some packages all layers are arranged in rows. The most popular package used is the lug box. This box has been used by California and Texas shippers for several years and is now used as a shipping container in nearly all regions. Other containers used for shipment, and also to some extent for local markets, are the 8-quart and 12-quart handled, square-braid basket and paperboard baskets. The 4-basket and 6-basket crate formerly used more than any other shipping container has been displaced largely by the lug box. Tomatoes for local markets are put up in all kinds of containers including hampers, round-stave and other kinds of baskets holding 3 or 4 pecks, and boxes and crates of various kinds. With the increasing competition from shipping sections, local growers will be forced to the use of better containers than they have used in the past. Some market gardeners are now adopting standard packages suitable for the product and others are expected to follow by force of circumstances.

The practice of wrapping tomatoes in paper before packing is a common one in many regions where the crop is grown for shipment.

Wrapped fruits stand long-distance shipment better than unwrapped fruits. Wrapping adds to the expense. Results of studies by Sando (1920) indicate that wrapping is objectionable because the wrapped fruit does not develop such good quality as unwrapped fruit. When the air is excluded the fruit develops high acidity, has a somewhat lower sugar content than fruit ripened in air, and has a poor flavor.

Storage.—Tomatoes can be kept in storage either in mature green or in more mature stage of maturity. For mature green fruits, the best storage temperature is from 50° to 60°F., especially if they are to be held for a considerable period. Wright *et al.* (1931) state that 55°F. was the lowest temperature at which the tomatoes ripened with good color and good flavor. They found that holding tomatoes at temperatures as low as 32°F. for 5 days did not prevent subsequent ripening, but the rate of ripening was slower than fruits not so exposed. Platenius, Jamison, and Thompson (1934) found that if tomatoes were kept at temperatures below 49°F. for longer than 2 weeks, they decayed rapidly when allowed to ripen subsequently at 70°F. Mature green tomatoes can be kept as long as 30 days at 50° to 60°F. Ripe tomatoes can be kept for 10 days at 40°F. The humidity of the storage room should be 95 to 98 per cent to prevent excessive shrinkage.

EGGPLANT

The eggplant is of minor importance as a commercial crop. According to estimates of the U. S. Department of Agriculture (*Agricultural Statistics*, 1938) the commercial crop acreage in Florida, Texas, Louisiana, and New Jersey in 1937 was 3,800 acres, producing 905,000 bushels having a farm value of $629,000. These figures do not cover all of the crop grown for market as it is grown for local markets in many states.

History and Taxonomy.—The eggplant is probably a native of India and has been in cultivation for a long time. Some authorities claim that it can be recognized from descriptions published as early as the fifth century. It probably was not known in Europe at the time of the ancients.

It belongs to the Solanaceae or nightshade family and is known under the botanical name *Solanum melongena.* Almost all of the cultivated varieties belong to botanical varieties of the species mentioned. The common eggplant, to which the large-fruited forms, such as New York Improved, belong, is known under the name *S. melongena* var. *esculentum.* The plant is bushy and grows to a height of 2 to 4 feet; the leaves are large and alternate on the stems; the flowers are large, violet colored, solitary, or in clusters of two or more. The serpentine or snake eggplants are placed under the variety *serpentinum.* The fruits of this group are long and slender, 1 inch or less in diameter and 12 to 15 inches long. The dwarf eggplants are known under the variety name *depressum.* These produce small, weak, spreading plants, nearly smooth. The leaves are small and thin, and the flowers are much smaller than those of the common eggplant. The fruits are small, pear shaped, and purple in color. The dwarf forms do not require so long to mature as the common form and are better adapted to regions having a short growing season.

Culture.—The cultural requirements of the eggplant are practically the same as for the tomato except that it requires a longer growing season and is more seriously checked in growth by cool weather. To be successful, the plants must not be checked in growth. Seeds are sown in a greenhouse or hotbed 8 to 10 weeks prior to the time the plants are to be set in the field or garden. The plants are always transplanted at least once before they are set outdoors and pots, plant bands, or other individual containers are often used so that there will be as little check in growth as possible when they are planted in the field. The eggplant is a hot-season crop; therefore the plants should not be set out until all danger of frost is over and the weather has become warm.

The plants are set 2 to 3 feet apart in rows 3 to 4 feet apart. For the large-growing varieties 3 by 4 feet is none too far apart.

Warm sand or sandy-loam, well-drained soils should be selected, especially in the North. Where manure is available at a moderate price, it can be used to advantage at the rate of about 15 tons to the acre and should be supplemented with fertilizer high in phosphorus. Where little or no manure is used, an application of 50 to 75 pounds of nitrogen and 100 to 150 pounds each of phosphoric acid and potash is suggested for sandy and sandy-loam soils. On heavier soils, 50 pounds each of nitrogen and potash and 100 pounds of phosphoric acid should be satisfactory.

Cultivation given the eggplant is practically the same as that given the tomato.

Varieties.—Relatively few varieties of eggplants are offered by American seedsmen. Three distinct colors, black, purple, and white are grown but the black-fruited varieties are the most popular. White-fruited varieties are seldom found on the market. Purple-fruited sorts are attractive, but the smaller size of the fruit is objectionable from the market standpoint.

The most popular varieties are New York Improved and Black Beauty. Other varieties listed by seedsmen are Black Pekin and Early Long Purple, the hardiest of all varieties and adapted to the cooler parts of the North. A new variety, New Hampshire Hybrid, developed by Hepler of the New Hampshire Experiment Station, is very promising for regions having a relatively short growing season. The fruits of this variety are oval to round, smooth, and somewhat smaller than Black Beauty.

Wilt (*Verticillium alboatrum*).—This disease causes a yellowing and wilting of the foliage and gradual defoliation. Affected plants make a stunted growth; many die prematurely. In the later stages the wood of affected plants shows a dark discoloration.

Crop rotation is recommended as a control measure.

Bacterial Wilt (*Bacillus solanacearum*).—This disease is caused by the same organism responsible for the bacterial wilt of the tomato.

Fruit Rot (Leaf Spot, Stem Blight) (*Phomopsis vexans*).—This is a serious fungous disease which attacks all parts of the plant above ground. The spots on the leaves are brown, circular or oblong, becoming irregular with age. The centers of the spots become grayish and the margins almost black. Spots on the fruit start with grayish or light brown blotches which develop into a soft rot, frequently covering the entire fruit. The disease on the stem is most common on the seedlings where it causes a damping-off.

Treating the seed with corrosive sublimate solution, 1 to 1,000, will kill the spores on the seed but will not reach the mycelium under the seed coat. It is considered worth while to treat the seed; Spencer, Zimmerley, and Davis (1924) recommended a 2-minute treatment and then washing the seed for 15 minutes in running water. Others suggest a 10-minute treatment. Spraying and dusting have been used with satisfactory results when the fungicides have been applied thoroughly. About five applications at weekly intervals, beginning as soon as the plants are well established in the field, are recommended. Two applications in the seedbed may be worth while.

Eggplant Flea Beetle (*Epitrix fuscula*).—This small black flea beetle is a very serious pest of the eggplant. It is especially injurious to the plants in the seedbed where it punctures the leaves and stunts the plants so that the first flowers often drop. Spraying with Bordeaux mixture, to which calcium arsenate (2 pounds to 50 gallons) is added, and dusting with copper-lime-calcium arsenate dust have given good results. Spencer, Zimmerley, and Davis recommend highly the dust treatment for the control of this insect.

Colorado Potato Beetle.—This insect is often very injurious to eggplant. (See p. 377.)

Eggplant Lace Bug (*Gargraphia solani*).—This insect is a small lace bug, about 1/6 inch long, which injures the plant by sucking the juices.

Spraying with whale-oil soap, 8 pounds to 50 gallons of water, or with nicotine sulphate, 8 ounces to 50 gallons of water, will aid in keeping this insect under control.

Eggplant Tortoise Beetle (*Cassida pallidula*).—This insect is widely distributed over the more southern portions of the United States, and has been reported from some of the northern states. Both the larva and adult injure the plant by eating holes in the leaves, and while they seldom cause great injury, at times they are quite destructive.

This insect feeds on the Irish potato and some of the wild species of Solanum. Jones (1916) found that the larvae could be kept under control by spraying with arsenate of lead, 1 pounds of powder to 50 gallons of water, and with arsenite of zinc, powdered, at the rate of 1 pound to 50 gallons of water. He recommends dipping the plants in some spray mixture at the time of field planting.

Harvesting.—The fruits of the eggplant are edible from the time they are one-third grown until they are ripe. They remain in an edible condition for some time after they become fully grown and colored. A heavier crop will be produced if the fruits are removed before they reach full size, but they should be well colored and of good size in order to sell well.

The fruits are usually cut from the vines since the stems are hard and woody. The large calyx and a short piece of the stem are left on the fruit, but care should be taken to prevent the stem from injuring other fruits in the package. They are heavy and should be handled with care even though they are not so perishable as the tomato. The fruits are sometimes put in paper bags, one fruit to each bag, or wrapped in paper before being packed for shipping. They are packed in various kinds of containers, including special crates, bushel baskets, and, to some extent, in berry crates. Before packing they are usually graded somewhat to separate the sizes and to cull out inferior fruits, but no definite grades are recognized.

PEPPER

The pepper belongs to the genus *Capsicum* and is very distinct from the pepper of commerce, which is the fruit of *Piper nigrum*, belonging to another family. Peppers are used in a great variety of ways. Cayenne pepper or red pepper of commerce consists of fruit of small pungent varieties ground to a fine powder. Pepper sauce of various kinds consists of the fruit of pungent varieties preserved in brine or strong vinegar. Tabasco sauce is said to be the juice of pungent varieties, expressed by pressure. Paprika, a Hungarian condiment, is made from fruit ground after the seeds have been removed. Peppers are used in pickles of various kinds; the sweet varieties are sliced and eaten as salad. They are used in stuffing pitted olives, and the large sweet varieties are stuffed and baked. A small-fruited variety of peppers is used for decorative purposes.

Peppers have very much the same cultural requirements as the eggplant, although the plants will withstand lower temperatures. They thrive best, however, in a warm climate and a long growing season. They are grown to a very limited extent in the eastern portion of the United States farther north than New Jersey.

Statistics of Production.—The production of peppers has increased considerably during recent years as is indicated by the estimates of acreage, production, and value of the crop in the nine important producing states as shown in Table LXIII. The importance of this crop is much greater than is indicated by the figures since it is grown in most of the other states, in some of which the acreage for local markets is considerable.

TABLE LXIII.—ESTIMATED ANNUAL ACREAGE, YIELD, AND VALUE OF PEPPERS GROWN FOR MARKET BY 5-YEAR PERIODS, 1923 TO 1937

Years	Acres	Yield, bu. per acre	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1923–1927	11,100	281	3,117	$1.34	$4,187
1928–1932	16,554	231	3,829	.92	3,524
1933–1937	18,382	222	4,080	.66	2,698

The leading states in the production of peppers for market in 1937 were Florida with 7,200 acres; New Jersey with 6,000 acres; California with 2,300 acres; Texas with 1,600; North Carolina with 1,500; and Louisiana with 1,200 acres.

In addition to the peppers grown for market, 11,030 acres of pimiento peppers valued at $545,000 were grown for manufacture in 1937. These were grown mostly in Georgia and California.

History and Taxonomy.—Peppers probably had their origin in tropical America, though numerous so-called species have been attributed to southern Asia. They were not known in Europe prior to the discovery of America and DeCandolle (Origin of Cultivated Plants) stated that no ancient Sanskrit or Chinese name is known for the genus and neither were the Greeks, Romans, or Hebrews acquainted with it. It was first mentioned by Peter Martyn[1] in an epistle, dated September 1493, in which he says Columbus brought home "pepper more pungent than that from Caucasus." Peppers were disseminated rapidly in Europe after the discovery of America. Three varieties were figured in 1542, 13 in 1611, 20 in 1640, and 35 in 1699. Linnaeus recorded two species in the first edition of "Species Plantarum" 1753, and three additional species were added by 1797. Oviedo (1514) mentioned the use of peppers in tropical America.

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[1] STURTEVANT, *Am. Nat.* **24**: 151, 1890.

Peppers belong to the Solanaceae family and to the genus Capsicum. While early botanists recognized many species, Bailey (1924) recognizes only one species, *C. frutescens* (*C. annuum* and *C. baccatum* L.) with 5 botanical varieties. Irish (1898) recognized two species, *C. annuum* and *C. frutescens* and listed all of the botanical varieties, under *C. annuum*.

The botanical varieties recognized by Bailey include the following:

Var. *cerasiforme*, Bailey, Cherry peppers. Leaves of intermediate size, ovate or oblong, 2–3 inches long; fruit erect or declined, spherical, subcordate or oblate, ½ to 1 inch in diameter, red, yellow or purplish, very pungent.

Var. *conoides*, Bailey, Cone peppers. Like cherry peppers but fruits conical, or oblong-cylindrical, 1–2 inches long, usually erect.

Var. *fasciculatum*, Bailey, Red Cluster pepper. Plant compact with narrow clustered leaves; fruits erect, fascicled, very slender, 3 inches long and ¼ inch thick, red, very pungent.

Var. *longum*, Bailey, Long peppers. Leaves medium to large; fruits mostly drooping, elongated 3–12 inches long and mostly tapering to apex, often curved, sometimes 2 inches thick at base; includes Long Red, Long Yellow, Chilli, Cayenne, and others.

Var. *grossum*, Bailey, Bell, or Sweet peppers. Plant stout and tall; leaves oblong-ovate, 4–5 inches long; flowers 1 inch or more across; fruits large and puffy with depression at base, the sides usually furrowed, either oblong, bell-shaped, or apple-shaped and tomato-like, red or yellow, mild in flavor.

Culture.—Peppers are grown in very much the same way as eggplants and tomatoes. The plants are started in greenhouses or hotbeds in most regions and are handled in the same manner as tomatoes. They are set out after all danger of frost is over and the weather is warm. The spacing of the plants is less than for either eggplants or tomatoes. Rows 2½ to 3 feet apart with the plants about 18 inches apart are the common distances. Pepper plants require continuous growth for satisfactory results. It requires at least 3 months' growing season to produce a profitable yield; a longer period is desirable.

The failure of pepper plants to set fruits under some conditions is one of the serious problems in many sections of the United States. Results of studies by Cochran (1936) indicate that unfavorable temperature and unfavorable water supply are the basic factors in the dropping of buds, blossoms, and small fruits. Low humidity and high temperature result in excessive transpiration and a water deficit in the plant. Under such conditions, abscission of buds, flowers, and very small fruits usually takes place. Low moisture supply in the soil is also an important factor in blossom drop, but under conditions of excessive transpiration a water deficit develops, even when the soil is well supplied with water. In Cochran's studies, plants held at 50° to 60°F. for about six months made no appreciable growth and from 40 plants only one flower developed and this dropped without setting fruit. When plants that had produced blossoms at higher temperatures were transferred to the 50° to 60°F.

house at the time of anthesis, practically 100 per cent of the flowers set fruit, but all were parthenocarpic fruits.

Varieties.—Two classes of peppers are grown, those which produce pungent or "hot" fruits and those which bear mild or sweet fruits, the latter being known as "sweet peppers." The most popular varieties of the pungent-fruited peppers are Tabasco, Long Red Cayenne, Red Chili, Red Cluster, Birdseye or Creole, and Cherry. Of the large-fruited, sweet peppers Ruby King, California Wonder, World Beater, Harris' Earliest, Harris' Early Giant, Ruby Giant, and Golden Queen are well known varieties (Fig. 61). Some of the relatively new varieties that are promising include Calwonder, Oakview Wonder, Harris Wonder, Waltham Beauty, Windsor A, and Windsor B. The Windsor A and Windsor B are early prolific varieties, the former producing fruits of medium green color, somewhat slender, while the latter produces fruits that are darker green in color and more blocky in form.

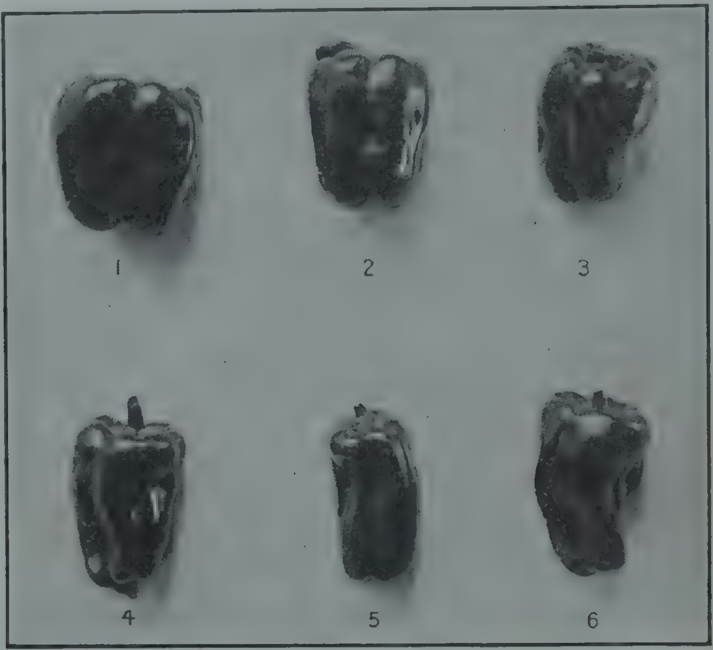

Fig. 61.—Peppers showing variation within a variety. (*Courtesy of Cornell Univ. Agr. Exp. Sta.*)

Pimiento or Spanish Pepper is a mild, thick-fleshed type, which has become popular in the United States during recent years. It is grown to a considerable extent in the South and is popular for canning. The term "pimento" is often used but the Spanish term "pimento" is applied to allspice, a species of aromatic trees. Pimiento peppers are usually smoother and more pointed, have thicker flesh, and are heavier than Bell peppers. According to Stuckey and McClintock (1921) an average bushel of ripe Spanish peppers weighs 33 pounds.

Of this amount 22.68 pounds are pulp or fleshy part used for canning, 5.15 pounds are cores, 2.06 pounds are stems, and 3.09 pounds are seeds.

Perfection is the best known variety of pimiento or Spanish pepper.

Diseases.—Weber (1932) lists the following diseases of peppers: Bacterial spot (*Phytomonas vessicatorium*), southern blight (*Sclerotium rolfsii*), Cercospora leaf spot (*Cercospora capsici*), anthracnose (*Gleosporium piperatum* and *Colletotrichum nigrum*), early blight (*Alternaria solani*), Phytophthora blight (*Phytophthora capsici*), pink joint (*Sclerotinia sclerotiorum*), bacterial soft rot (*Bacillus aroideae* and *B. carotovorus*), mosaic, sunscald, blossom-end rot, and several others. Many of these diseases are the same or similar to those attacking tomatoes and the control measures are essentially the same. Seed treatment, seedbed sterilization, and crop rotation are control measures that should be taken in growing peppers.

Insects.—The pepper plant is seldom injured to any great extent by insects although it is sometimes attacked by the potato aphis, flea beetle, potato beetle, and spinach aphis.

Harvesting.—The stage of maturity at which peppers are picked depends on the purpose for which they are grown and the demand of the market. The large sweet peppers are usually picked while still green in color when they are sold on the general market, although there is some demand for red ones. Canners demand a bright red color.

The fruits will remain on the plants for some time after reaching maturity without deterioration. They are usually picked by snapping off the brittle stems with the hand.

Peppers are packed for market in various kinds of containers including the half-bushel, bushel and half-barrel hamper, bushel stave basket, and to some extent, in 4- and 6-basket carriers.

Storage.—While peppers usually are not stored for any considerable period, experimental results reported by Platenius, Jamison, and Thompson (1934) indicate that they can be kept in good condition for at least 40 days at 32°F. and at humidity of 95 to 98 per cent. Shrinkage of the fruits stored under these conditions was only 4 per cent in 40 days, which is less than for most vegetables. At 40°F. pepper fruits kept well for about 4 weeks and at 50°F. they remained in good condition for 16 days. At temperatures from 50° to 70°F., breakdown is caused by softening, wilting, and shriveling.

HUSK TOMATO

The husk tomato (*Physalis pubescens*) is cultivated to some extent in the gardens of the United States, but it is not grown commercially. The plants are decumbent and produce a small, round fruit of a yellow color inside a thin husk. There are several native species of Physalis known as "ground cherry." The fruits of the husk tomato are sometimes used for preserves. They may be eaten raw but they are rather insipid in flavor.

The plants are easily grown and are handled in the same manner as tomato plants. In general the cultural requirements of the husk tomato are the same as for the tomato.

CHAPTER XXVI

THE CUCURBITS OR VINE CROPS

CUCUMBER	WATERMELON
MUSKMELON	PUMPKIN AND SQUASH
	CHAYOTE

The cucurbits or vine crops are tender annuals grown for their fruits. They thrive only in hot weather and will not withstand frost. All of these crops belong to the same family, Cucurbitaceae, and all have similar cultural requirements as well as many of the same diseases and insect pests. From every point of view they should be grouped together for discussion. While most of the plants in this family are monoecious, some are andromonoecious and some are dioecious.

CUCUMBER

The cucumber is an important vegetable crop, being grown in the home garden, in market gardens, on truck farms in the South for shipping to northern markets, as a forcing crop, and as a special crop for the pickle factories in various parts of the United States. The cucumber is widely used in salads and in mixed pickles.

Statistics of Production.—The production of cucumbers for use in the fresh state increased markedly since 1918, as is shown in Table LXIV.

TABLE LXIV.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF CUCUMBERS GROWN FOR MARKET BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield, bu. per acre	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1918–1922	17,530	147	2,572	$1.81	$4,665
1923–1927	33,866	128	4,327	1.52	6,560
1928–1932	46,846	98	4,607	1.05	4,819
1933–1937	43,114	85	3,683	.89	3,290

The figures in Table LXIV include only the cucumbers grown for market in the 17 most important producing states. Other states also produce some cucumbers for market. While the acreage has increased markedly since 1918, the yield per acre and the price received have decreased. The average price received in the period 1933–1937 was slightly less than half that received in the 1918–1922 period. The low price probably is due, to a considerable extent, to the reduced purchasing power of consumers. The leading states in acreage of cucumbers for market in 1937 were Texas with 7,300 acres; Florida and South Carolina with 5,600 acres each; North Carolina with 4,500 acres; and New Jersey with 3,500 acres.

The acreage and production of cucumbers for pickles increased steadily from 1918 to 1937, as is shown in Table LXV. In 1937 the total acreage of cucumbers for pickles was 108,610 acres. Michigan was the leading state with 29,000 acres; Wisconsin second with 16,650 acres; Ohio third with 6,000 acres; North Carolina fourth with 5,670 acres; Texas fifth with 4,800 acres; and Virginia sixth with 4,600 acres.

TABLE LXV.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF CUCUMBERS GROWN FOR MANUFACTURE BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield, bu. per acre	Production, bu. (000 omitted)	Price per bushel	Value (000 omitted)
1918–1922	57,156	57	3,264	$0.95	$3,088
1923–1927	77,904	53	4,147	1.04	4,308
1928–1932	79,176	63	4,972	0.76	3,794
1933–1937	84,854	65	5,492	0.54	2,941

During the years 1918 to 1937, the production per acre showed a general upward trend, but the price received was markedly downward during the last two periods.

Climatic Requirements.—The cucumber is a warm-season crop and the plant is killed by a light freeze, but because it matures a crop in a relatively short season (60 to 70 days) it is grown in most all sections of the United States. Kotowski (1926) has shown that the cucumber seed does not germinate at a temperature as low as 11°C., but that the seed may remain in cold soil for a considerable time and then germinate when the soil temperature becomes favorable. According to Kotowski, the lower limit of germination is between 11° and 18°C. The percentage, as well as the speed of germination, increases at higher temperatures up to 30°C.

High humidity is favorable to the development of diseases on the foliage.

History and Taxonomy.—The cucumber is probably a native of Asia and Africa and has been in cultivation for thousands of years. There is evidence that its culture in western Asia dates back at least 3,000 years and it is said that the cucumber was introduced into China from the west about 140 to 86 B.C. It was known to the ancient Greeks and Romans, and Pliny even mentions their forced culture (Sturtevant). The cucumber was known in France in the ninth century and was common in England in 1327. It was grown by the early colonists in America and is said to have been grown by the Indians in Florida in 1539.

The cucumber belongs to the genus Cucumis of which there are 20 to 25 species found mostly in Asia and Africa, only two, *C. sativus* and *C. Melo*, being of much importance in the United States. A third species, *C. Anguria*, West Indian Gherkin, is found in the South and in tropical America. The cucumber is a trailing or climbing plant with hairy, angular stems and large leaves with long petioles. The flowers are axillary, the staminate being more numerous than the pistillate.

Soil Preferences.—Cucumbers can be grown on almost any type of soil. Where earliness is a prime consideration, a sandy or a sandy-loam soil is selected, but where heavy yields are most important a good loam or clay loam is preferred. On the heavier soils the yields are usually larger and the bearing period longer than on light soils. The soil should be well drained but retentive of moisture, especially for a late crop. In the South where cucumbers are grown during the winter and spring for shipping to northern markets, a sandy-loam soil is usually selected.

Manures and Fertilizers.—Manure is often used in growing cucumbers, but it is not essential as good yields are obtained by the use of commercial fertilizers and soil-improving crops. Results of 12 years' experiments reported by Comin and Bushnell indicate that 16 tons of manure applied to an alluvial soil at Marietta, Ohio, produced larger yields and greater net profits than commercial fertilizers. The manure was charged against the crop at $3.75 per ton. Manure often costs more than this when purchased in cities and when the cost of hauling and applying is added. The highest application of nitrogen in commercial fertilizer was 480 pounds of nitrate of soda; it is possible that more nitrogen would have increased the yields and profits. Another factor that should be taken into consideration in judging the profits from manure is the price received for cucumbers. When the price averages relatively low, 16 tons of manure at $3.75 could not be justified. In the Ohio experiments superphosphate added to the manure did not increase the yield. Lime had no appreciable effect on the yield of cucumbers on this soil which is acid (pH about 5.6).

Some growers follow the practice of applying small quantities of manure—4 or 5 tons in the row. The manure is covered with soil and the cucumber seed is planted over the manure. Where larger applications of manure are made it is best to apply it broadcast, but it is doubtful if large quantities of manure are generally justified. It is usually more profitable to use light, or moderate, applications of manure and to supplement it with fertilizers. When manure is not used some soil-improving crop should be grown to turn under and fertilizer added to supply the nutrients. The quantity of nutrients to apply should be determined by the richness of the soil, the cropping system followed, and the returns that might be expected from the crop. On unmanured sandy and sandy-loam soils, a fertilizer supplying 35 to 50 pounds of nitrogen and 75 to 100 pounds each of phosphoric acid and potash to the acre should be satisfactory. On silt-loam and clay-loam soils, an application of 25 to 30 pounds each of nitrogen and potash and three or four times as much phosphoric acid is suggested.

Planting.—Since the plant is tender and the seeds will not germinate in a cold soil, planting should be delayed until all danger of frost is over. Market gardeners often take chances on an early planting since earliness is an important factor. Some growers plant seed at two different depths at the same time, the shallow planting coming on first; if these plants are killed by frost the deeper planting coming up later will be likely to escape. Other growers make two or three plantings side by side at intervals of a few days and after the danger of injury is over they select the planting which gives the greatest promise. The other plantings are destroyed.

Planting in hills was formerly the universal practice and is still preferred by some growers, but a large part of the crop is planted in drills. When planted on a large scale planting in hills is seldom practiced at present. When the hill method is used the hills are spaced 4 by 5, 5 by 5, or 6 by 6 feet apart, depending on the soil. On light soils of only moderate fertility 4 by 5 feet is sufficient, but in a rich soil a greater space should be given. In the hill system, several seeds are planted in each hill; after the plants are well established, they are thinned to two plants. The main advantage of the hill method of planting is that the cultivator can be used in both directions. In the drill method the seeds are sown with a drill in a continuous row using 2 to 3 pounds to the acre; after the plants are well established, they are thinned to stand 1½ to 3 feet apart in the row. The rows are spaced 4, 5, or 6 feet apart. The plants are much better distributed in the drill system than in the hill system and much less labor is required in planting.

In some regions cucumber plants are started under cover several weeks prior to the time it would be safe to plant in the open. In the vicinity of Norfolk, Va., the seed is sown in rows in cold frames as for field culture. When the weather gets warm, the sash and the frames are removed. At this time the vines are usually running and in blossom. Ordinary field cultivation is given after the frames are removed. Market gardeners in the North often start cucumber plants in the greenhouse or hotbed and later set them in the field. The seeds are usually planted in pots, plant bands, veneer bands, or tin cans, although they are sometimes started in flats and transplanted to the individual containers while the plants are still small. It is important to have the plants in receptacles so that the roots will not be disturbed when the plants are set in the field. This method of starting plants is practicable only for an early crop which is likely to bring a high price. For the general crop the extra expense of growing the plants in the greenhouse or hotbed would not be justified.

Cultivation.—Frequent shallow cultivation should be given as long as possible without injuring the vines. Weeds should be kept down by cultivation until the vines cover the ground and then large weeds should be pulled by hand.

Varieties.—There are very few varieties of cucumbers grown in the United States. White Spine or Arlington White Spine, Kirby, Early Fortune, Clark Special, A & C or Ace, and Straight Eight are the most popular varieties for slicing cucumbers and also for dill pickles. Chicago Pickling, Snow Pickling, National Pickling, and Double Yield Pickle are the most popular varieties for small pickles. For forcing, the White Spine and crosses between it and the English forcing type are commonly used. One of these crosses, the Abundance, is a very popular forcing variety in some sections. The English forcing varieties are not very popular in this country, but are grown to some extent in greenhouses on private estates.

Diseases.—Cucumbers are attacked by several diseases, any one of which may make production unprofitable. In many regions disease is the main limiting factor in profitable production of this crop and the pickle industry has been forced to abandon production in region after region because of serious losses. The most important diseases of the cucumber are bacterial wilt, anthracnose, mosaic, downy mildew, angular leaf spot, scab, and root knot. Many other diseases attack it but they are seldom of great importance.

Bacterial Wilt (*Erwinia tracheiphilus*).—This disease is caused by bacteria that are carried by insects, especially the striped cucumber beetle. Wilt is usually the first disease to appear and often causes the plants to wilt and die when they are still small. It may continue to attack the plants throughout the season. A cut stem shows a sticky ooze which will adhere to the finger and can be drawn out into threads. This disease also attacks muskmelons, watermelons, squashes, and pumpkins.

The disease spreads from the leaves downward into the petioles and stems until the entire plant has wilted and died. The fruit also wilts and shrivels. The bacterium apparently lives over winter in the digestive tract of the striped and the 12-spotted cucumber beetles so that if the beetles are eradicated the wilt will disappear. The bacteria reach the leaves of the plants through the feces of the beetles and infections takes place only through wounds that are deep enough to reach the vascular tissue.

Control depends on eradicating the beetles or protecting the foliage with a fungicide to kill the bacteria before they enter the tissues. Since the disease may be carried from diseased to healthy plants by insects, it is desirable to pull and destroy plants as soon as the wilt shows up and to keep the foliage well covered with a fungicide and an insecticide. Bordeaux and copper-lime dusts have a retarding effect on the growth of the plants, and for this reason, some authorities suggest delaying applications as long as is feasible. Control measures for cucumber beetles are suggested later (see p. 494).

ANTHRACNOSE (*Colletotrichum lagenarium*).—This disease is very destructive to cucurbits, including the cucumber. It is usually more severe on the watermelon than on the other cucurbits, although it may appear in epidemic form on cucumbers and muskmelons. All parts of the plant above ground may be infected. On the leaves of cucumbers and muskmelons, the spots begin as small yellowish or water-soaked areas which enlarge rapidly and turn brown, while watermelon vines present a black or scorched appearance. The fruits first show water-soaked, sunken spots. Masses of buff-colored spores are found in the spots.

According to Melhus and Elmer (1925), the anthracnose does not exist in land that has never grown cucurbits; therefore, the best way to control it is to prevent its introduction into the soil. The organism may live in the soil on diseased plant refuse for at least a year and perhaps longer. Crop rotation, seed treatment with corrosive sublimate solution (1 ounce in 7 to 8 gallons of water), and spraying with Bordeaux mixture will aid in controlling this disease. In seed treatment the seed is left in the solution for 5 minutes, then rinsed thoroughly in running water and dried.

MOSAIC.—This disease is known by various names such as mosaic, white pickle, white wart, nubbin disease, and chlorosis. Next to bacterial wilt it is probably the most serious disease affecting cucumbers. It kills the vines in the greenhouse and stunts them in the field as well as causing the cucumber to develop into nubbins. The muskmelon is also severely affected by it.

The cause of mosaic is unknown, but it is very infectious. It is not transmitted through the soil or the seed. According to Doolittle (1924) the disease is not carried over in the striped cucumber beetle, but it does live over in the wild cucumber, the milkweed, the pokeweed, and the wild ground cherry. In the wild cucumber it is carried over in the seed. The disease is carried from diseased to healthy plants by insects and by other means, such as on knives used for pruning cucumbers in the greenhouse.

The control measures recommended include the eradication of the wild hosts for a considerable distance around the greenhouse and around the cucumber field, the removal of diseased plants as soon as they can be detected, and the control of insects, especially melon lice.

DOWNY MILDEW (*Plasmopora cubensis*).—This disease attacks the leaves during warm moist weather. Angular yellowish spots appear on the foliage causing a yellowing, followed by curling and death. The oldest leaves are attacked first.

Thorough spraying with Bordeaux mixture, every week or 10 days, beginning when the disease first appears, will afford control.

Dusting with copper-lime dust has been used successfully in Maryland and Virginia for the control of this and other diseases. Jehle and Potts (1924) report increase in yields of 10 to 15 per cent by spraying and dusting muskmelons in Maryland, and an improvement in the quality of the fruit. They recommend spraying or dusting as soon as the vines begin to run.

ANGULAR LEAF SPOT (*Bacterium lachrymans*).—This disease appears as small angular spots, which are at first water soaked and later turn brown. On the stem the disease appears as lesions somewhat irregular and elongated. It may also appear on the fruits as water-soaked spots. Soon after infection an exudate appears in the spots, which become white. The organism enters the plant through the stomates of the leaves, and after infection takes place the bacteria multiply rapidly. The disease spreads through the transfer of the bacteria by splashing rains, by winds, by drainage water, by insects, or through workmen handling the plants. The disease winters over in the seed.

Seed treatment with corrosive sublimate solution, as suggested for anthracnose, rotation of crops, spraying, or dusting are the control measures recommended.

SCAB.—This disease, caused by *Cladosporium cucumerinum*, occurs on cucumbers, muskmelons, and pumpkins. The affected leaves have water-soaked spots and become wilted, the stems have slight cankers, but the main injury occurs on the fruit where there is oozing of sap at first. Later the spots increase in size and become sunken cavities lined with a greenish mold. The scab organism lives over winter in old refuse and on the seed.

Crop rotation, seed treatment with corrosive sublimate and red-copper-oxide dust, and spraying with 2–1–50 or 4–2–50 Bordeaux mixture, or dusting with 15–15–70 dust are the treatments recommended. The weaker Bordeaux is recommended for muskmelons.

Insects.—All parts of the cucumber plant are attacked by insects most of which also prey upon other cucurbits. While some of the insects seem to have a preference for a particular species of cucurbits, they will attack others when the one they prefer is not available. Thus the squash-vine borer and the squash bug seem to prefer squash and pumpkin plants although they feed upon the other species.

Striped Cucumber Beetle.—This is probably the most serious insect pest of the cucumber and melon. It attacks the plants as soon as they come up, devouring the leaves and eating the stems. The main injury is done by the overwintering adults attacking the young tender plants. The beetles also carry the cucumber wilt, while the larvae burrow into the roots and cause the plants to wilt, but this injury is seldom noticed.

Among the measures recommended for control are (1) covering the plants with screen wire or cheesecloth on frames, (2) destroying old vines and trash at the end of the season, and (3) applying material to repel or kill the insects. Covering hills of plants with wire-covered or cheesecloth-covered frames is practiced to some extent in home gardens and in small commercial plantings, but this method is not practicable on a large scale. Burning the old vines and trash at the end of the season will destroy many of the beetles and remove their protection.

Spraying with arsenicals has been recommended but it is not very effective when the insects are numerous. Dusting the plants with arsenicals and nicotine-impregnated dusts has been used successfully in many regions. White (1922) protected cucumber plants at Arlington Farm, Rosslyn, Va., with a dust made of 72 pounds of kaolin, 24 pounds of lime, and 4 pounds of nicotine sulphate. He tested various strengths of nicotine-sulphate dusts and found that 4 per cent was as effective as higher percentages. Cardinell and Page (1922) found that 4 per cent nicotine dust controlled both lice and striped beetles in Missouri. Dudley, Wilson, and Mecum (1923) in Wisconsin and Cory and Potts (1924) in Maryland also successfully controlled beetles by nicotine dusts. Houser and Balduf (1924) in Ohio found that plants dusted with mixtures containing hydrated lime were retarded in growth, but were not affected by gypsum. Huckett (1929) reported that heavy applications of spray material and dusts reduced the yield of melons on Long Island. He found that arsenical sprays were less harmful than arsenical dusts. Houser and Balduf found that dusting once a week with dust containing 1 part of calcium arsenate to 20 parts of gypsum ($CaSO_4$) was the most satisfactory control for beetles of all. Since there is some objection to the use of arsenicals, rotenone dust is recommended, especially for cucumbers. A dust containing $^3/_4$ of 1 per cent rotenone with talc as a diluent is recommended. Treatment should begin as soon as the beetles appear and should be repeated at intervals of one week as long as they are present.

Twelve-spotted Cucumber Beetle.—This insect feeds on a large number of food plants, including the cucurbits. On the cucumber and related plants, its injury is similar to that of the striped cucumber beetle but it is not serious in the North. The control measures are the same.

The larva is a serious pest of corn in the South where it feeds on the roots and is known as the southern corn rootworm. It also feeds on roots of other plants, but especially the grasses.

SQUASH BUG.—This insect is a true bug with a very offensive odor, giving rise to the name "stink bug." The adult lives over winter in trash and comes out of hibernation and attacks the plants as soon as they come up. The insects puncture the tissues of the leaves and petioles and suck the juices causing the leaves to wilt. The eggs are brownish in color and are deposited in patches on the underside of the leaf. There are five stages in the development of this insect, all of which often can be seen on a single leaf.

The adult is resistant to contact sprays. Burning the trash in the fall, trapping the adults under boards in the spring, hand picking of the adults, and destroying the eggs are suggested control measures. The young bugs can be destroyed by thorough dusting with a pyrethrum dust containing from $\frac{5}{10}$ to $\frac{9}{10}$ of 1 per cent pyrethrins.

SQUASH-VINE BORER.—The larva, or borer, tunnels in the main stem near the surface of the ground and usually decay sets in. The first evidence of injury is the wilting of the entire plant which is often followed by death. While this insect attacks all cucurbits, it prefers squash and pumpkin.

The control measures recommended are (1) to plant early squash as a trap crop to be destroyed later, (2) to cut out borers as soon as there is any evidence of their presence, (3) to cover the stems with soil to induce new root growth, (4) to burn old vines as soon as the crop is harvested, (5) to plow deeply in the spring to prevent the moths from emerging, and (6) to practice crop rotation.

Results of experiments indicate that nicotine sulphate is effective in killing the eggs when applied at a strength of 1 pint to 12½ gallons of water with 4 ounces of soap flakes if a hand sprayer is to be used. When applied with a power sprayer, one-half of this strength is needed. Fish-oil soap, 4 pounds to 100 gallons of water, may be substituted for the soap flakes. Derris and cube dust containing 1 per cent of rotenone has given fairly good control when applied with a bellows type of duster.

SQUASH LADY BEETLE.—Nearly all lady beetles are predaceous and are therefore beneficial rather than injurious, but the squash lady beetle is an exception. The larvae feed upon the underside of the leaves of cucurbits and the adults feed upon the upper side at the same time. This insect seems to prefer the squash and pumpkin, but will feed on melon and cucumber vines. It is usually a minor pest. If serious, spraying or dusting with an arsenical is recommended.

MELON APHIS.—The melon aphis, commonly called the "melon louse," is a small sucking insect that injures the plants by sucking the juice. It feeds mostly on the underside of the leaves and often escapes notice until the leaves begin to curl. It attacks a large number of plants, including all of the cucurbits and cotton in the South. It is less troublesome on squashes and pumpkins than on cucumber and melon plants.

The melon aphis can be controlled by thorough spraying or thorough dusting with nicotine preparations. Chittenden and White (1926) suggest that treatment with nicotine dust be made when there is little air movement, when the temperature is about 70 °F., and when the foliage is dry. The underside of the leaves must be covered with spray, or dust, for the treatment to be successful.

THE CUCUMBER OR POTATO FLEA BEETLE.—This insect injures the plant by eating holes in the leaves. (See p. 377.)

PICKLE WORM (*Diaphania nitidalis*).—This is a serious pest of muskmelons, cucumbers, and squashes in most sections of the South; it occasionally occurs in destructive numbers as far north as New York, Michigan, and parts of Canada. The young larvae burrow into the tissue of the blossom or bud, and on the squash they may complete their growth in the blossom, but on cucumbers and muskmelons they usually migrate to the fruit. Some burrow down into the stem and complete their growth there and cause injury to the vines, but the greatest injury is caused by burrowing into the fruit.

The newly hatched larva is about 1⁄16 inch long and the full-grown caterpillars attain a length of 3⁄5 to 2⁄3 inch. In some sections of the South there are four, and occasionally five, generations a year.

Spraying and dusting with arsenicals have not been successful in controlling this pest. Destroying waste fruits and vines by burning or composting is recommended. Other control measures suggested are planting early so that the crop may be harvested before the second and third broods appear and growing squash vines as traps.

Harvesting.—Cucumbers are picked on the basis of size rather than age, the size being determined largely by the purpose for which they are grown. For slicing cucumbers, they are picked when they are 6 to 10 inches long; for pickles, they are harvested when they are 2½ to 6 inches long. Very small cucumbers are in demand for mixed pickles, and small to medium-sized ones are preferred for dill pickles. Small-sized cucumbers are less profitable to the grower than the larger ones because of low yields of the former. Frequent picking is important as the cucumbers grow rapidly and soon get beyond the marketable stage. None of the fruits should be allowed to ripen on the vines as the development and maturing of the seeds cause a heavy drain on the plant.

Cucumbers are picked by hand, care being taken to avoid injuring the vine. The stems is left attached to the fruit.

Grading.—Cucumbers for slicing are graded on the basis of size, shape, and general appearance. The U. S. Department of Agriculture has worked out specifications that should be generally followed where systematic grading is practiced. These specifications are changed frequently and for this reason are not given here. Usually field-grown cucumbers should be separated into two grades; in some cases, three grades might be used to advantage.

Cucumbers for pickles are graded according to size and, where grown on contract, the price differential is given in the contract. The smaller sizes bring the highest price per bushel. Of course, the shape and general appearance of the cucumbers are taken into consideration along with the size.

Packing.—Cucumbers for market are packed in various kinds of packages including hampers, bushel baskets and crates, and boxes of many kinds. Lug boxes and 12-quart handled baskets have become popular in recent years. For fancy packs, these containers are used much more than are bushel baskets or hampers.

With all types of containers the cucumbers should be well placed and tightly packed so there will be no shifting in the package. Fancy grades, especially of greenhouse cucumbers, are usually placed by hand in the package and attention is given to the attractiveness of the display when the package is opened.

When shipped long distances, cucumbers are usually loaded into refrigerator cars under refrigeration. For short hauls, local freight and express shipments are common, and refrigeration is not used.

MUSKMELON

The muskmelon, melon, or cantaloupe is a popular crop although it is not an easy one to grow in most regions of the United States. It is grown in many home gardens, in market gardens, and as a special crop in many sections of the United States, but especially in arid regions where irrigation is used.

The commercial production of the muskmelon is of recent development. Prior to 1870 it was seldom seen on American markets. It was first grown commercially in New Jersey, Delaware, and Maryland.

It was not until after the Netted Gem was introduced by Burpee in 1881 that muskmelon culture developed extensively as a trucking industry in regions located long distances from the markets. This type of melon, which is small, round, or oval in shape and has a hard rind, is much better adapted to shipping long distances than the varieties previously grown.

The muskmelon industry at Rocky Ford, Colo., began to assume importance about 1896 with the formation of the Rocky Ford Melon Growers' Association. In 1905 the Imperial Valley of California became important as a melon-producing region and is now by far the most important section in the United States.

Statistics of Production.—The muskmelon is one of the important vegetable crops grown in the United States. The estimated average annual acreage, production, and value of the muskmelon crop grown in 26 important states from 1918 to 1937 are shown in Table LXVI. Of course, the figures do not represent all the crop grown as they do not take into consideration those grown for market in other states.

TABLE LXVI.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF MUSKMELONS (CANTALOUPES) BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield, crates per acre*	Production, crates (000 omitted)	Price per crate	Value (000 omitted)
1918–1922	73,502	142	10,442	$1.64	$17,083
1923–1927	95,122	142	13,545	1.52	20,528
1928–1932	122,922	136	16,674	1.10	18,280
1933–1937	109,480	121	13,234	.97	12,837

* Standard crates (45's) containing approximately 60 pounds.

The acreage and production of melons increased steadily up to 1931; since that time there has been some decline, due probably to the general economic conditions. During the last 5-year period, the total value of the crop shows a sharp drop.

In 1937, California produced about one-third of the acreage and nearly one-half the total production of the 26 states referred to above. Arizona was second in both acreage and production with 10,000 acres and 1,250,000 crates. Other important producing states in that year were Maryland, Indiana, Colorado, Georgia, Texas, Michigan, and New Jersey.

Climatic Requirements.—The muskmelon thrives best and develops the highest flavor in a hot, dry climate; for these reasons, a large part of the commercial crop is produced in California, New Mexico, Arizona, and Colorado where the atmosphere is dry during the ripening period. In these states the crop is grown under irrigation. In humid climates the plants grow well, unless injured by diseases and insects, but the fruits do not ripen so well in a normal season as they do in arid regions. If the weather is cloudy or rainy during the ripening period, melons are rather insipid. In addition to this, foliage diseases are especially serious in humid regions. Diseases not only reduce the yield but also affect the quality since the fruits do not develop good flavor when most of the foliage has been killed by disease.

The muskmelon requires a longer growing season than does the cucumber, but otherwise the requirements are similar. High temperature and sunshine seem to result in high sugar content and good flavor, factors that make the Southwest the important muskmelon-producing region of the United States.

History and Taxonomy.—Although the muskmelon has never been found growing wild, it is believed to have originated in Asia. It is not of ancient culture as no reference is found to it in the early literature. Columbus found it growing on Isabella Island in 1494 and it is mentioned as being grown in Central America in 1516, in Virginia in 1609, and along the Hudson River in 1629.

The muskmelon, *Cucumis Melo* Linn., belongs to the family Cucurbitaceae and to the same genus as the cucumber. The fact that it is so closely related to the cucumber has led growers to attribute poor quality of the muskmelon to cross-fertilization. This, however, certainly does not normally take place. Many attempts have been made by investigators to produce a hybrid from these two species, but without success. Pollen from the cucumber applied to the stigma of the muskmelon flower does not result in fertilization.

Authorities recognize the following botanical varieties of *Cucumis Melo* as proposed by Naudin:

Var. *reticulatus*, netted melons: fruits small with ribbed and netted surface.

Var. *cantalupensis*, cantaloupe melons: fruits warty, scaly, and rough, with hard rinds, surface often warted. This type is practically unknown in the United States. The name cantaloupe is improperly applied to melons in general, or to certain types.

Var. *inodorous*, winter melon, casaba melon: fruit with little of the musky odor, ripening late, and keeping into the winter; surface usually smooth.

Var. *flexuosus*, snake or serpent melon: fruit long and slender, 1 to 3 inches in diameter and 18 to 36 inches long, curved and crooked. Used to some extent for preserves, but grown mostly as a curiosity.

Var. *Dudain:* fruit small, about the size of an ordinary orange, surface marbled with rich brown, very fragrant; grown mostly for ornament and strong scent.

Var. *Chito:* mango melon or lemon cucumber; fruit small, the size of a lemon, used in making preserves, called mango preserves. The fruits are known as orange melon, melon apple, and vegetable orange.

The melons commonly grown in the United States belong to *Cucumis Melo*, var. *reticulatus*. All of the varieties commonly seen on the market, with the exception of the casaba and Honey Dew, belong here.

Soil Preferences.—Muskmelons are grown on a great variety of soil types. Where earliness is an important factor, as in most regions of the North, a sandy loam is considered the best. In fact, this type of soil is considered almost ideal in most regions, although other soils are used in regions where the growing season is long. The soil should be well drained, as melons do not thrive on a water-logged soil. Any friable, well-drained soil is satisfactory provided the other conditions are favorable to melon growing.

Muskmelons do not thrive well on a highly acid soil; when such soils are used, lime should be applied. Most authorities recommend a range from pH 6.0 to pH 6.7. Melon plants grown on a soil that is very acid make very poor growth and the leaves develop a yellowish-green color, sometimes known as "acid yellowing" (Fig. 62).

Manures and Fertilizers.—Manure is considered valuable in growing muskmelons and many growers in the North believe that the crop cannot be grown successfully without it. Without it, good crops are produced by the use of commercial fertilizers and soil-improving crops. When manure is used in small quantities (5 tons or less per acre) it is best applied in the row or in the hill, but with large applications broadcasting is safer and better. Lloyd (1912) reported results of experiments carried on for 3 years on an unglaciated silt-loam soil and for 5 years on a gray silt loam in Illinois in which manure applied in the hill was more profitable than commercial fertilizers. Small applications (2.5 to 3 tons) in the hill produced a greater net profit than large applications (4.5 to 12 tons per acre) applied in the same way, although the yields were larger from the heavier applications. Results of later experiments reported by Lloyd (1929) show that 10 tons of manure produced a larger yield of melons than any combination of cover crop and fertilizer, but it should be

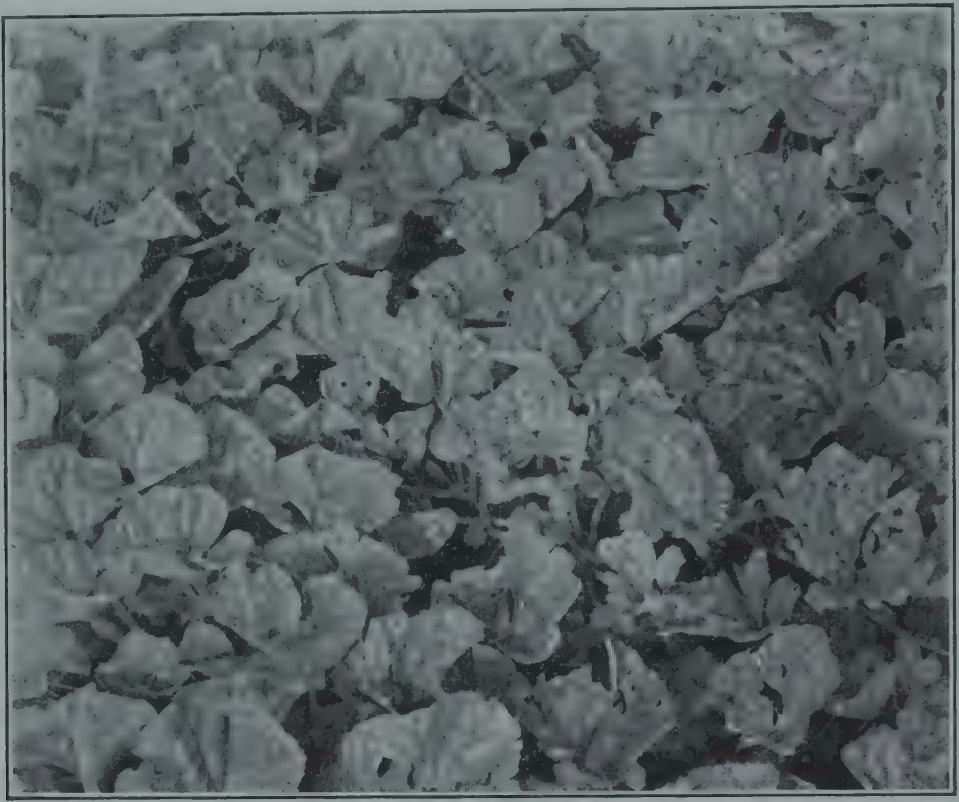

FIG. 62.—Muskmelon foliage showing acid yellowing. (*Cornell Univ. Agr. Exp. Sta.*)

noted that no plot received a complete fertilizer. It is possible that a complete fertilizer supplying the nutrients in optimum quantity would have produced as profitable yields as 10 tons of manure.

Edmond, Strand, and McNall (1930) give results of experiments in Michigan in which commercial fertilizers, 300 to 600 pounds of a 3–12–4, produced practically as large yields as manure applied at the rate of 8 tons in the hills or 16 to 20 tons broadcast. They state, however, that the humus content should be maintained and that this can be done by growing green-manure crops. Their data indicate that 300 pounds of fertilizer applied in the hill produced a greater number of early fruit and a larger total yield than 600 pounds applied broadcast. They suggest that where as much as 600 pounds of a 3–12–4 fertilizer is used it is desirable to apply half of it in the hill and the other half as a later dressing.

A considerable part of the melon crop is grown without manure by using soil-improving crops to maintain the humus supply and fertilizers to supply the deficient nutrients. Data presented by Wilkins (1917) indicate that the muskmelon removes considerable quantities of potassium, calcium, and nitrogen and small quantities of phosphoric acid, as is shown in Table LXVII.

TABLE LXVII.—TOTAL QUANTITY OF NUTRIENTS REMOVED BY MUSKMELONS
(*N. J. Bull.* 310)

Part of plant	Pounds per acre						
	Green weight	Dry weight	Nitrogen	Phosphoric acid	Potassium oxide	Calcium oxide	Magnesium oxide
Vines	3,132	939	19.8	3.8	28.2	53.5	6.8
Fruit flesh	11,310	1,154	20.5	7.7	48.7	8.4	5.0
Seed	2,175	307	9.8	3.9	13.5	0.5	1.8
Total	16,617	2,400	50.2	15.4	90.3	62.2	13.5

Most of the calcium is in the vines and is returned to the soil on decomposition. The melon fruits and seeds remove large amounts of nitrogen and potash and when the crop is grown on soils deficient in these elements they should be supplied in considerable quantities.

Results of experiments on a gravelly sandy-loam soil in New York, reported by Carolus and Lorenz (1938), show the need of a liberal application of potash where the soil is low in available potash. Where manure was not used, 100 pounds of potash (K_2O) seemed to be needed; doubling the quantity reduced the early yield. When melons are grown on sandy and sandy-loam soils without manure, an application of fertilizer supplying 50–75 pounds of nitrogen and 100 pounds each of phosphoric acid and potash is suggested. There appears to be no need for this quantity of phosphoric acid, but other crops grown will make use of the surplus. Where manure is used, the fertilizer application should be less. On silt-loam soils the potash application might be cut in half.

Growing Plants.—A part of the muskmelon crop, grown in regions having a short season, is produced from plants started in greenhouses, hotbeds, or cold frames. The seeds are usually planted in pots, plant bands, or other receptacles, since the seedlings do not withstand the shock of transplanting well when they attain considerable size. Several seeds are planted in each receptacle and the plants are thinned to one or two when they are well established. Some growers prefer to sow the seed in flats. Five to seven days later when the seed leaves have developed, but before the first true leaves appear, the seedlings are transplanted into pots, plant bands, or other receptacles, one plant to each. It is very important to transplant the plants while they are very small, otherwise growth will be seriously checked and many will not survive. This is one reason why planting the seed in pots or bands is generally recommended.

Planting in the Field.—Muskmelon plants are very tender and the seeds will not germinate at low temperatures, hence planting in the field should be delayed until all danger of frost is over and the soil has become warm. Plants should be set before they develop more than four leaves and before they become pot bound; for this reason the seeds should not be planted more than 5 or 6 weeks before it is safe to set them in the field.

A large part of the commercial crop is grown from seed planted in the field. While the hill method is still used, drilling the seed is more common in large plantings. The methods of planting in hills and in drills are practically the same as described for the cucumber. When planted in drills the usual rate is 2 to 3 pounds of seed to the acre.

Plant protectors, made of various kinds of paper, are used in the growing of muskmelons in many parts of the United States to protect them against chilling. These protectors are used in the Imperial Valley on a very large scale and to some extent in many other regions to place over hills of melon seed. In some regions they are used also to protect the melon plants when set in the field, after having been grown in greenhouses, hotbeds, or cold frames. They protect plants from wind injury as well as against cold, and have considerable effect on earliness. Ware (1936) showed that protectors (hotkaps) hastened germination of the seed, markedly increased the early yield, and increased the total yield over 25 per cent. These results were obtained in Arkansas over a period of 3 years; somewhat similar results on early yield were obtained by Edmond, Strand, and McNall (1930) in Michigan.

In the use of plant protectors, care should be taken to prevent damage to the plants during hot days. After the plants are well started, it is necessary to provide ventilation under the paper during warm days. Slitting the paper on one side, usually away from the wind, is the method used. After the danger of cold weather is over, the top may be torn out of the protector, leaving a collar of paper to protect the plant against whipping in the wind. When plants begin to run, the protectors should be removed.

Cultivation.—Frequent shallow cultivation should be given until the vines interfere. Some growers continue cultivation after the veins meet between the rows, but it is probable that more harm than good is done since the plants are easily injured. Moving the ends of the vine with a stick may be justified, but turning them from one row to the other may seriously injure them. Cultivation after the vines cover a considerable portion of the ground is probably of little, if any, value unless weed growth is heavy. Large weeds may be pulled by hand after cultivation ceases. Hand hoeing in the row may be desirable while the plants are small.

Varieties.—Simple methods of classifying varieties of muskmelons into a few groups or classes have been suggested by various workers. One method is based on color of flesh, separating varieties into groups: (1) those with green or white flesh and (2) those with salmon or yellowish flesh. This method is not of much value since separating the varieties into two groups is no great help in identification. Other methods of classification that have been suggested are based on size, shape, color, and smoothness of the surface—whether netted or not netted, ribbed or not ribbed.

In selecting varieties of muskmelons for market, the grower should take into consideration the demands of the consumer especially with reference to size of melon, color of flesh, quality, and surface markings. After determining the consumer's preferences he should consider varieties with reference to yield, disease resistance, earliness, shipping quality, keeping quality, and other factors that might affect profits. Some varieties of high quality are poor shippers and for that reason are adapted only for home use and for local markets. Others are excellent shippers but of low quality. For long-distance shipping the varieties should possess good shipping qualities, such as a thick rind, relatively solid flesh, slow ripening, and uniform size and shape; at the same time they should be of good quality.

The most important varieties of muskmelon or cantaloupes are Hale Best, of which there are many strains, Powdery Mildew Resistant

No. 45, Pollock 10–25, Hearts of Gold, Honey Rock, Champlain, Bender or Bender's Surprise, Market King (Pride of Wisconsin, Queen of Colorado, Jersey Gold, Marvel), Emerald Gem, grown some for home use and for local market, and many others that are grown to some extent. Some of the older varieties showing range in size, shape, and netting are illustrated in Figs. 63 and 64. Most of these are still grown.

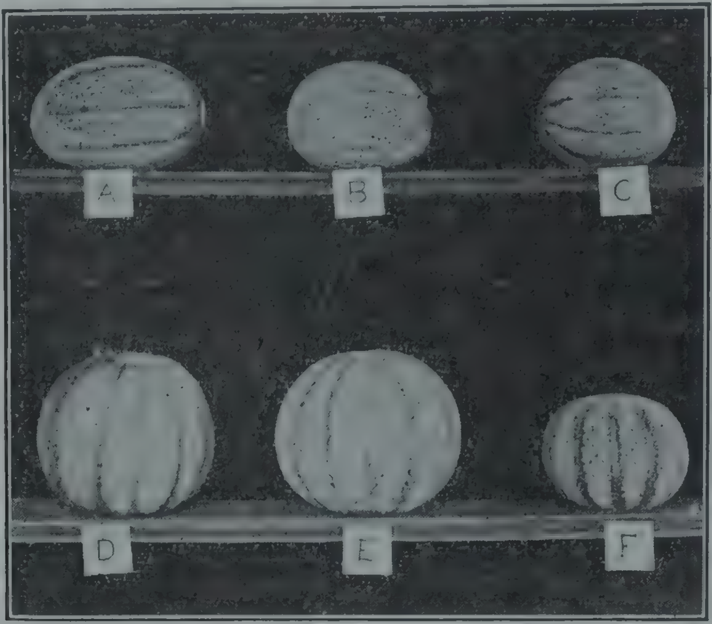

FIG. 63.—Varieties of muskmelons—*A*, Burrell Gem; *B*, Rocky Ford; *C*, Paul Rose; *D*, Irondequoit; *E*, Bender's Surprise; *F*, Round Jenny Lind.

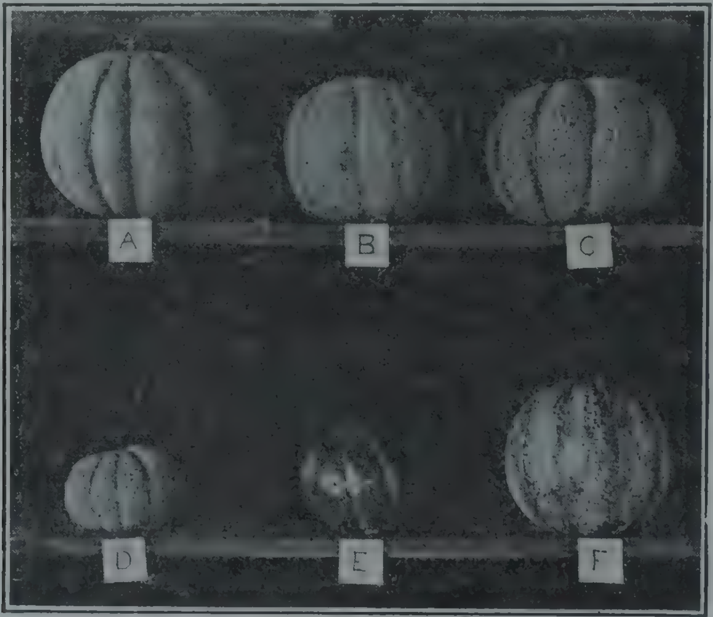

FIG. 64.—Varieties of muskmelons—*A*, Angelo; *B*, Milwaukee Market; *C*, Hackensack; *D*, Jenny Lind; *E*, Emerald Gem; *F*, Miller's Cream.

In addition to the types known under the trade name of "cantaloupes" there are others known as "casaba" and "honeydew." The name casaba is applied to a group rather than to a single variety. The plants are larger and coarser and the leaves are more deeply lobed than are those of the common types of muskmelons. The fruit is firm, with thick, white flesh and small cavity, which is almost completely filled by the placenta and seeds. The fruits either are smooth or have numerous small, long, longitudinal grooves converging at the stem end. The peduncle does not absciss on ripening so that the main indication of maturity is the development of a deep yellow color in the skin and the softening of the fruit at the stylar end. The flesh does not have the musky odor characteristic of ordinary muskmelons, or the high sugar content. The casabas, of which there are several varieties, thrive only in warm, dry climates.

The honeydew belongs to the same group as the casabas, but the plant and fruit characters are more nearly like those of the common varieties of muskmelons. The fruit is ivory white, the skin is smooth, the flesh is thick and greenish; there is also a pink-fleshed strain. The sugar content of the honeydew when ripe is higher than that of the casaba, and somewhat higher than in most common varieties of muskmelons.

Diseases.—The muskmelon is attacked by the same diseases as the cucumber and the same methods of control may be applied.

FUSARIUM WILT.—In addition to the diseases discussed in connection with the cucumber, the muskmelon is attacked by one or more species of *Fusarium*. This disease is capable of destroying the entire crop, once the soil becomes heavily infested. The disease is present in Minnesota, in parts of New York, and possibly in other states.

The plants first show a stunting and yellowing, followed by a streak on the side of the stem that may extend only a few inches or for the entire length of the vine. The streak at first is water soaked in appearance, then becomes yellowish tan in color. In some cases there is no definite streak, but the vine cracks open and sap oozes out. The plant soon dies. The fungus lives in the soil for many years and also may be carried in the seed; high temperature is favorable for its growth.

No definite control measures are known. Long rotations and destruction of diseased refuse are suggested. The development of resistant varieties seems to be the logical method of attack. Such work is in progress in Minnesota and in New York and the results, so far obtained, look very promising.

Insects.—All the insects discussed under cucumber also attack the muskmelon, and the same methods of control are recommended. In addition, the melon worm (*Diaphania hyalinata*) is often injurious in the South and occasionally as far north as New York and Michigan.

The adult is a moth with white wings marked with a brown band along the margins. The full-grown caterpillar is about 1 inch long, and greenish yellow in color, somewhat mottled. The first brood feeds on the foliage and does little damage to the fruit. The larvae of the later generations attack the fruit, feeding on the surface and burrowing through the rind. Decay sets in almost immediately and the fruits are worthless. The control measures suggested are (1) to plant squashes ahead of the melons to serve as a trap crop, (2) to spray or dust with arsenicals, and (3) to destroy the vines and waste fruits as soon as the crop is harvested.

Harvesting.—The stage of maturity at which melons should be picked depends on the length of time required to reach the market, on the variety, on the temperature at harvest time, and on the method of shipping. Casabas and honeydews are commonly harvested in a somewhat immature condition, and while they ripen and soften in transit, the best quality is not obtained unless the fruits are allowed to mature on the vines. The casaba may be picked in autumn and stored in a cool, dry room for 2 or 3 months, or longer.

For local markets, muskmelons should be left on the vines until they are fully mature, but still solid; for shipment, they are picked before they are fully ripe and, in many cases, so immature that they never develop good, edible quality.

It is difficult to determine the stage of maturity at which melons should be picked for long-distance shipment since there is no definite external character correlated with approaching maturity. There are certain changes that take place that may be used as an index, but these should be correlated with the internal condition. As melons approach maturity, the netting becomes fully rounded out, whereas in immature melons the netting is flattened and has a slight crease along the top. The color showing through the netting changes from a dark green or grayish green to a yellowish green as the melon nears maturity. As ripening advances, a crack develops around the peduncle at the base of the fruit and when fully ripe the fruit slips easily from the stem leaving a large scar; this is known as the "full slip." In the "half-slip" stage, only a portion of the disk is removed when the fruit is pulled from the vine and the scar on the fruit is smaller than in the "full-slip" stage.

Chase, Church, and Denny (1924) have shown that the soluble solids, the refractive index, and the sucrose content of the juice of muskmelons increase and the percentage of starch in the seeds decreases as the melons ripen. Edible quality depends on texture, flavor, and sweetness. The sugar content is the most important factor and this may be estimated by determining the soluble solids in the juice of the edible portion. "The juice of melons that are mature when picked has a specific gravity of at least 1.040, equivalent to 10 per cent total solids, a refractive index of at least 55 on the immersion refractometer, and a sucrose content not less than 4.5." The method generally used is to measure, with a hydrometer, the specific gravity of the juice. Several fruits are cut and the edible portion of the melon is spooned out and passed through a food chopper. The juice is then squeezed out through a cheesecloth, placed in a tall cylinder, and allowed to stand for 5 minutes. A spindle hydrometer, graduated into degrees Brix, is placed in the juice and the top reading is taken and corrected for temperature. The reading in degrees Brix corresponds to the per cent of soluble solids calculated as sucrose.

Immature melons are lower in soluble solids than are the more mature ones. There is, however, only a slight increase in soluble solids as the melon passes from the half-slip to the full-slip stage and there is a slight decrease in the "field-ripe" melons. The rapid respiration of melons ripening in the field uses up some of the sugar; this accounts for the decrease in soluble solids.

Chase, Church, and Denny found that melons could not be picked on the basis of color of skin, on stem abscission, or even on the disappearance of the crease on the netting although there was a slight correlation between maturity and the disappearance of the crease. They found that 50 per cent of the melons showing a faint crease on top of the netting were edible, but only 15 per cent with a distinct line on the net were ripe enough to slip. Melons gain in flavor, but not in sweetness, after being picked. For this reason fruits picked green never become sweet.

Careful and prompt handling after the melons are picked is very important. Rough handling causes bruises which make them more susceptible to decay. Delay in getting the melons packed and loaded into refrigerator cars may result in too rapid ripening with consequent loss on the market. Table LXVIII shows the effects of delayed loading of muskmelons in the Imperial Valley on their condition on arrival in New York City as reported by McKay, Fischer, and Nelson (1921). The figures are based on 13 shipments of comparable lots.

TABLE LXVIII.—CONDITION OF MUSKMELONS (POLLOCK) HELD 1, 4, AND 8 HOURS BEFORE LOADING INTO REFRIGERATOR CARS, ON UNLOADING IN NEW YORK CITY, AND TWO DAYS LATER, 1917

Condition of melons	On unloading			Two days later		
	1 hr., per cent	4 hr., per cent	8 hr., per cent	1 hr., per cent	4 hr., per cent	8 hr., per cent
Too soft to be desirable..........	8.4	16.7	27.0	30.6	34.7	43.2
Too yellow—overripe............	8.4	13.3	15.0	20.9	21.5	26.3
Decayed enough to spoil for food..	...	....	1.2	2.9	3.3	4.4

Relation of Composition to Quality.—Attention has been called to the fact that the soluble solids and sugar content increase with maturity, as indicated by the slipping of the stem. Chase, Church, and Denny have shown that this index of maturity is not always reliable and they determined the relation between composition and quality, as judged by taste. A summary of the results of their studies is given in Table LXIX.

There is an increase in refractive index, soluble solids, and sucrose as the melons pass from the inedible to the high-quality fruit. The difference between the various classes of fruit is more striking when determined by tasting than when determined by external characters. In determining the stage of maturity for picking, it is best to cut a number of melons and test their quality by tasting them, and then to correlate the taste with the appearance of the fruits at the time.

Grading.—Grade specifications for muskmelons (cantaloupes) have been worked out by the U. S. Department of Agriculture; these should be used whenever feasible. The specifications are changed from time to time and for this reason they are not given here.

Table LXIX.—Relation between Composition of the Juice of Melons and Their Eating Quality

(Chase, Church, and Denny, 1924)

	Quality of fruits as determined by tasting			
	High	Satisfactory	Doubtful	Inedible
Tulare, California				
Refractive index	63.0	58.5	54.0	45.5
Soluble solids, per cent	12.0	11.0	10.0	7.9
Sucrose, per cent	6.58	5.29	4.13	2.04
Turlock, California				
Refractive index	60.50	57.08	49.9	45.0
Soluble solids, per cent	11.60	11.0	9.1	7.7
Sucrose, per cent	6.12	5.39	3.55	1.77
Brawley, California				
Refractive index	60.0	58.7	50.7	44.6
Soluble solids, per cent	12.3	11.9	10.1	8.6

Western-grown melons are usually better graded that those grown in the East, but none are so well graded as they should be. The fruits should be carefully graded with reference to size, shape, color, and general appearance. Fully ripe melons should be packed separately and disposed of on near-by markets, as they will not stand long-distance shipping. Soft, green, off-type, bruised, and very small melons should be discarded, and only those that will reach the market in good condition should be packed.

Packing.—Muskmelons for local markets are seldom packed; those that are to be shipped are always put up in packages of some kind. Crates of various sizes, holding from 12 to 54 melons, are the most popular type of package. Downing (1921) gives dimensions of 16 crates that are in common use in the United States. These range in size from 4 by 12 by 22½ inches inside dimensions in the California pony flat crate to 12 by 12 by 22½ inches for the California standard crate. Downing states that the number of sizes could be reduced to six, possibly to four, types without interfering with the standard pack. The suggested sizes are:

	Inches		
Standard	12	× 12	× 22½
Pony	11	× 11	× 22½
Standard flat	4½	× 13½	× 22½
Pony flat	4	× 12	× 22½
Jumbo	13	× 13	× 22½
Jumbo flat	5	× 14½	× 22½

Reducing the number of sizes would eliminate much confusion and at the same time reduce the expense of manufacture.

Melons in the standard crate are placed three wide, three deep, and four or five long, the crate holding 36 or 45 fruits. Smaller melons are packed in the pony crate in the same way except that six melons are sometimes placed in a row lengthwise of the crate. The standard flat crate holds 12 to 15 melons; one layer deep, three melons wide, and four or five long. It is important that the melons be of uniform size. When the crate is packed, every melon on each side should touch the slats, and the crate when covered should bulge slightly on all sides. Unless there is a slight bulge, the pack will be loose when it reaches the market and the fruits are likely to be bruised by shaking about in the crate.

Casaba and honeydew melons are packed in special crates. According to Spillman and Davis (1929) three crates, the pony, standard, and jumbo, are used, the last two being the most important. The inside dimensions of these are as follows:

	Inches		
Pony	5¾	× 14½	× 22⅛
Standard	6½	× 16	× 22⅛
Jumbo	7½ or 7¾	× 16	× 22⅛

Outside length of slat for all sizes is 23½ inches.

Wrapping muskmelons in paper is practiced to some extent, but is not to be recommended as the paper excludes the air, keeps the surface moist, delays refrigeration, and discourages inspection.

Storage.—Melons ordinarily are not stored. Results of experiments by Platenius *et al.* (1934) and by Wiant (1938) indicate that they can be kept for a short period. Platenius *et al.* kept mature muskmelons for a month at 32°F. and at relative humidities of 80 to 90 per cent, and they were in good edible condition when removed. Wiant states that cantaloupes removed from refrigerator cars can be held for a week or longer at 32° to 34°F. Honeydew melons, he states, can be held two weeks either at 32° to 34°, or 36° to 38°F. Longer storage may be practicable. He found low-temperature breakdown on honeydew melons but not on cantaloupes. This breakdown developed more at 32° to 34° than at 36° to 38°F. It did not develop at all at 38° to 40°, or at 40° to 42°F.

WATERMELON

The watermelon requires a long, and relatively hot, growing season for its best development; for this reason it is grown largely in the South. However, the crop can be grown successfully in many of the northern states if early-maturing varieties are selected. In regions having a short growing season (4 months or less) watermelons can be produced only if the plants are started in greenhouses or hotbeds a few weeks prior to the time for planting in the field.

The watermelon is grown in many countries, but is more popular in the United States than elsewhere. It is used mainly as a dessert, but the rind is used to some extent in making conserves and pickles.

Statistics of Production.—The acreage, production, and value of the watermelon crop produced in the 23 important states, as reported by the U. S. Department of Agriculture (*Agricultural Statistics*, 1938), are given in Table LXX. While the acreage has increased markedly in the 20 years from 1918 to 1937, the value during the last 7 years of this period was less than in the years preceding. It should be said, however, that from 1930 to 1937 an appreciable portion of the crop was not harvested because of market conditions. These unharvested melons were included in the estimates of production but excluded in computing the value of the crop. A good illustration of the effect of the economic conditions on returns from a luxury product is shown by comparing the production and value of the watermelon crops of the years 1929 and 1932; in 1929 the total production

TABLE LXX.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF WATERMELONS IN 23 IMPORTANT PRODUCING STATES BY 5-YEAR PERIODS, 1918 TO 1937

Year	Acres	Yield, melons per acre	Production, melons (000 omitted)	Price per 1000 melons	Value (000 omitted)
1918–1922	143,510	371	53,247	$169.29	$ 9,014
1923–1927	180,954	317	57,412	190.88	10,959
1928–1932	238,004	302	71,773	122.53	8,794
1933–1937	259,766	246	63,842	104.62	6,679

was estimated at 70,996,000 melons and the farm value estimated at $12,047,000; in 1932 the corresponding figures are 63,865,000 melons valued at $4,442,000.

The most important producing states in 1937 were Georgia with 64,000 acres; Texas with 46,000 acres; South Carolina with 21,000 acres; Florida with 19,500 acres; California with 17,600 acres; Missouri with 13,000 acres; Alabama with 13,000 acres; and North Carolina with 11,600 acres.

History and Taxonomy.—The watermelon was unknown in Europe until the sixteenth century. Africa is considered to be its native home. It was found growing wild by Livingstone (1854) in regions not previously visited by white men. Carrier (1924) reports evidence indicating possible American origin. Early French explorers found Indians growing watermelons in the Mississippi Valley. As early as 1629 the watermelon was grown in Massachusetts and by Indians in Florida prior to 1664.

The watermelon belongs to the genus Citrullus, of which there are four species, but only two are of economic importance—C. *colocynthis*, the bitter gourd and C. *vulgaris*, the watermelon and the citron, or stock melon. The fruits of C. *colocynthis* are small, bitter, and inedible, but are used in making a drug.

Climatic Requirements.—The watermelon, like other cucurbits, is tender to frost and requires a long growing season with relatively high temperatures. It is not grown successfully as far North as is the muskmelon. The watermelon is not so much affected by atmospheric humidity as is the muskmelon. From the standpoint of both edible and shipping qualities, it is produced equally well in humid regions of the Southeast and in the arid regions of the Southwest and West. Foliage diseases are more destructive in humid than in arid climates.

Soil Preferences.—The watermelon thrives best on a sandy-loam soil, although other loams are used for the production of this crop in the South. In regions having a short growing season only the lighter soils should be used for this crop. Good drainage is essential for best results as watermelons will not thrive in a water-logged or poorly drained soil.

The watermelon is one of the few vegetables that grows well on a soil that is rather highly acid, as pH 5.0. This does not mean that it does not grow well at a higher pH, but that it is not necessary to apply lime to reduce the acidity of a soil of pH 5.0.

Fertilizer treatments suggested for muskmelons would be satisfactory for watermelons, but usually less fertilizer is used than for muskmelons. In the South, a large part of the crop is grown in rotation with farm crops, rather than with other vegetables.

Planting.—The time and method of planting watermelons are practically the same as for muskmelons, except that they require more room and a longer growing season. In regions having less than 4 months' frost-free period, watermelons cannot be grown successfully unless the plants are started under protection 3 or 4 weeks prior to the time when it is safe to plant them in the field. Under most conditions, watermelon production is not profitable where it is necessary to start the plants under cover in order to mature the fruit before frost in the fall. For home use and for special markets, starting plants in greenhouses, hotbeds, or under plant forcers may be justified. When the plants are to be grown in greenhouses or hotbeds, it is best to start the seeds in plant bands, flower pots, or other receptacles as the seedlings do not withstand transplanting very well. Several seeds are planted in each receptacle; when the seedlings begin to crowd they are thinned to a single plant, or two or three plants in each.

Nearly all the commercial crop is grown from seeds planted in the field. These are planted in hills spaced 8 by 8, 8 by 10, 10 by 10, 10 by 12, or 12 by 12 feet apart. Beattie (1924) states that Texas growers obtain the greatest returns per acre from 12 by 12 feet planting distances. After the plants are well established they are thinned to 1, 2, or 3 plants per hill. Some growers plant in rows and thin the plants to 3, 4, or more feet apart in the row. This method gives a better distribution of plants, but cultivation can be done in only one direction.

When manure is used, it is a common practice to apply some or all of it in the furrow or under the hill. In either case the manure is covered with loose soil to the depth of 2 or 3 inches. It is claimed that the manure hastens the germination of the seeds and the development of the seedlings. This is undoubtedly true where fresh manure is used as this undergoes heating and warms the soil. In the South this is of little consequence, but in regions having a short growing season hastening germination and growth may be very important.

The quantity of seed required depends on the method of planting. In hills the usual rate is 2 to 3 pounds to the acre, while in the drill method 4 to 5 pounds is ordinarily used. It is advisable to use a liberal quantity as the cucumber beetle often destroys a large percentage of the plants.

Cultivation.—Watermelons should be given about the same cultivation as cucumbers and muskmelons. When the plants are small the soil may be stirred with a harrow run between the rows. In the hill method of growing, the harrow may be run in both directions, leaving only a small amount of space at the intersections that would need to be hand-hoed. After the plants grow to considerable length, but before they meet in the middle, a small cultivator should be used instead of the large harrow. When the vines meet, cultivation usually ceases; but large weeds should be pulled by hand.

Varieties.—In selecting varieties of watermelons for planting, one should consider the purpose for which the crop is grown. If for home use or for a local market, quality should be the first consideration, but size, shape, yield, and other factors must also be considered. When grown for shipment, the melons should be solid and have a relatively thick rind or there will be serious losses in handling due to breakage. The grower, however, should not lose sight of the importance of quality, for low quality limits consumption and lowers the price. A good market melon is one that stands shipment well and is of good quality. There is more demand for small to medium-sized melons than for very large fruits. In selecting varieties for planting in regions with a short growing season, earliness is an essential.

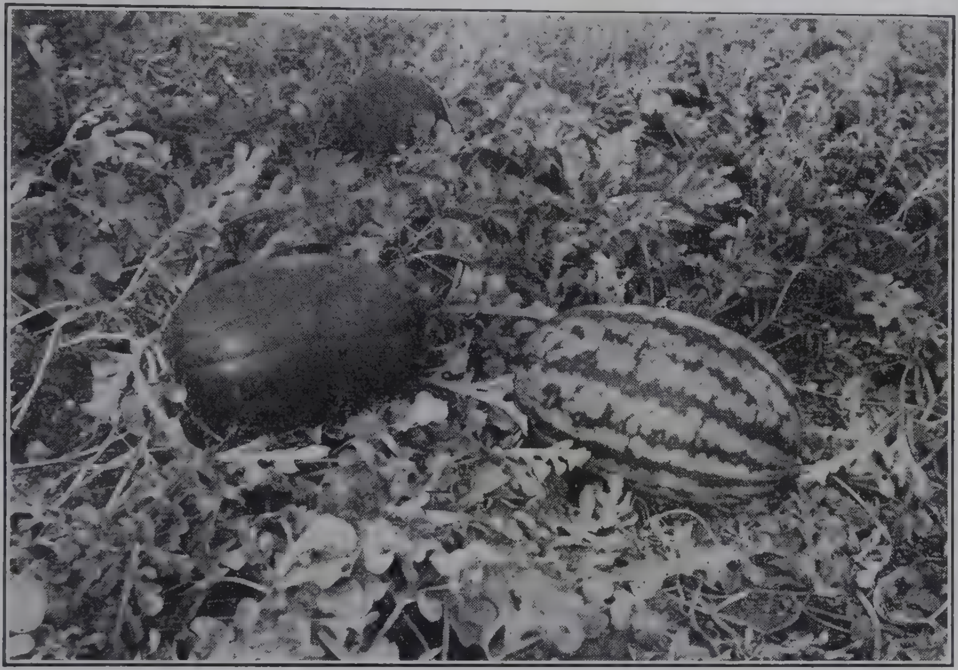

Fig. 65.—Two varieties of watermelons. Klondyke and striped Klondyke. (*Cornell Univ. Agr. Exp. Sta.*)

Markets of the East prefer a long, cylindrical fruit, rather than a short round one, but the markets of the Pacific coast prefer the latter. While there are many varieties of watermelons only a few are of much importance. Some of the important commercial varieties are Watson or Tom Watson, Cuban Queen or Dixie Queen, Stone Mountain or Dixie Belle, Kleckley, Klondike (Fig. 65), Early Kansas, and Early Arizona. The last two are early varieties of good quality that look promising in parts of the North where the standard varieties of the South are not satisfactory. Honey Cream, a small melon with lemon-yellow color, is gaining in popularity in a few sections of the North for home use and for sale on roadside and local markets. This variety is of good quality; the flesh is crisp and fine in texture.

Where fusarium wilt is very serious, some of the wilt-resistant varieties are grown, as Klondike R 7 in California, the Leesburg in Florida and elsewhere in the South, Iowa Belle, Iowa King, and Pride of Muscatine in some of the northern watermelon-growing regions. These varieties are discussed on p. 515.

Preserving Melon or Citron.—This fruit resembles a small watermelon, of light green color, usually round or oval in form. The flesh is white in color and is not edible. The rind is used for making conserves and sweet pickles, and the melon is sometimes fed to hogs. It is also known as "stockmelon."

The preserving melon has about the same cultural requirements as the watermelon. It crosses readily with it and has been used in breeding to produce a wilt-resistant watermelon.

Diseases.—The watermelon is attacked by a number of diseases, the most important ones being wilt, root knot, anthracnose, stem-end rot, blossom-end rot, and ground rot. Both the vines and fruit are affected. Orton (1917) gives the following descriptive key to watermelon diseases:

(*A*)	The vines wilt suddenly, beginning at the ends of the branches	Wilt
(*B*)	The vines lack vigor and the melons remain small; roots greatly enlarged	Root knot
(*C*)	The leaves show dark spots and tend to shrivel up	Anthracnose
(*D*)	The fruit is spotted with small pits	Anthracnose
(*E*)	The fruit decays at the stem end	Stem-end rot
(*F*)	The fruit decays at the blossom end	Blossom-end rot
(*G*)	The fruit decays where it rests on the ground, with abundant white mold	Ground rot

WILT (*Fusarium niveum*).—Vines affected by this disease wilt suddenly, beginning at the tips of the branches. One branch after another wilts until the whole plant is dead. The woody portion of the stem is discolored. The organism lives in the soil and grows up through the water-conducting tissues. These become plugged and the vine wilts.

No satisfactory method of control has been discovered, but Orton states that the following measures have been found to be of importance: (1) rotation of crops, (2) control of drainage water to prevent water from an infected field running over an uninfected field, (3) avoidance of stable manure, (4) control of livestock, and (5) resistant varieties. When land becomes infected with the wilt organism it should not be used again for melons for 8 to 10 or 12 years. The organism grows well in stable manure hence its use is not advised where wilt is serious. In addition to this, many stables become infected from portions of vines brought in with hay cut from the melon fields after the crop is off. Livestock may spread the wilt if they are allowed to range from an old melon field to other fields planted later to melons. Several varieties of watermelons that are resistant to the wilt have been developed. The Conqueror, developed from a cross between the Eden and the stock melon by the U. S. Department of Agriculture, is resistant, but is of little or no value commercially. It has, however, been used by Porter and Melhus (1932) in the development of Iowa Belle and Iowa King, two varieties that are wilt resistant. Porter (1937) developed Klondike R 7, a wilt-resistant variety, from a cross between Iowa Belle and Klondike. Leesburg is a wilt-resistant variety, developed by Walker (1936) in Florida, by selection from Kleckley Sweet. Pride of Muscatine, a selection of Kleckley Sweet developed by the Iowa Station, is another wilt-resistant variety of the Kleckley Sweet type.

ROOT KNOT.—This disease is produced by a species of nematode (*Heterodera radicicola*) widely distributed in the South, and very destructive to many vegetables and other crops. For a discussion of the symptoms of the disease and the control measures read the discussion under "Cabbage" (p. 281).

ANTHRACNOSE (*Colletotrichum lagenarium*).—The anthracnose is one of the most troublesome diseases of the watermelon. It affects the leaves, vines, and fruit. On the leaves and stems, the disease appears as irregular dark spots. The leaves dry up and die prematurely. On the fruits, the spots appear at first as water-soaked areas, but later they are sunken and covered with a pink growth of spores. These spots are usually small and there may be hundreds on a single fruit. At first they are shallow but become deeper and may result in the decay of the flesh when followed by other fungi.

Spraying the vines with 4–4–50 Bordeaux mixture is the most practicable method of control according to Meier (1920), who has made a considerable study of anthracnose. He recommends three applications: the first when the vines begin to run, the second about 1 week after the melons have "set," and the third about 2 weeks after the second. Other measures suggested are the use of anthracnose-free seed, rotation of crops, and avoidance of cultivating when the vines are wet.

STEM-END ROT (*Diplodia sp.*).—This is a disease affecting the fruit at all stages of development and may cause serious loss in transit even if it does not show at the time of loading. The first indication of the disease is a browning and shriveling of the stem. Decay of the fruit begins at the point of attachment to the stem. The flesh becomes soft and takes on a water-soaked appearance. The decay progresses rapidly and under moist conditions it becomes covered with a dark gray mold

The same type of decay may begin on the side of the melon where there is an injury.

Orton (1917) suggests the following control measures: (1) clean up the fields; (2) gather and destroy all cull melons; (3) spray for anthracnose, as the fungus that causes stem-end rot does not attack a healthy vine, but will grow on leaves and stems killed by anthracnose and thence be carried to the melons; (4) use great care to prevent injury in handling; and (5) disinfect the stem at the car. The disinfection of the stem at the time of loading at the car is the most important. The material used for disinfection is starch paste with copper sulphate. The paste is made of 8 ounces of starch and 8 ounces of copper sulphate dissolved in 1 gallon of hot water. One quart of paste is sufficient to treat a carload of melons and it should be used while fresh. The melons should be picked with about 2 inches of stem; when loaded into the car, the stem end should be turned outward. The stem is cut back so as to expose a fresh surface which is painted with the starch-copper sulphate paste.

BLOSSOM-END ROT.—This disease is common in many fields, but little is known about it. According to Orton it begins (or seems to begin) with an imperfect fruit. Later these fruits are invaded by decay-producing fungi. The Diplodia or stem-end rot is the most common, but other fungi also occur. Prompt destruction of cull melons is the control measure suggested.

GROUND ROT (*Sclerotium rolfsii*).—This rot begins on the side of the melon in contact with the soil. The fungus causing this disease is very common in the South and attacks many other plants. A heavy growth of white mold and the formation of many, roundish brown bodies the size of buckshot characterize this disease. Decay begins where there is an injury to the surface. The only control measure is the destruction of the affected fruits.

Chemical Injury.—Shippers and railroad employees frequently report injury to watermelons in transit, which they attribute to contact with chemicals, including fertilizer materials, left on the walls and floors of cars. Gilbert and Meier (1929) conducted experiments with 10 chemicals including common salt, nitrate of soda, sulphate of ammonia, sulphate of potash, muriate of potash, superphosphate, and two kinds of mixed fertilizers. They found two general kinds of injury: a sunken, corroded, leathery appearance, produced by superphosphate and a browning, water-soaking, withering, and softening of the melons caused by several chemicals. Thorough cleaning of the cars, combined with the use of paper on the side walls and sufficient straw on the floor, prevented the injury.

Insects.—The watermelon is attacked by the same insects as the cucumber. The melon aphis is more injurious to the watermelon than to either cucumber or muskmelon. For a discussion of the insect pests of the watermelon see under "Cucumber."

Harvesting.—It is very important that watermelons be at the proper stage of maturity when they are picked, but this is very difficult for the inexperienced to determine. With no other vegetable or fruit is there so little evidence of a change from immaturity to maturity. Neither the size of the fruit nor the color of the rind gives an indication of ripeness. Perhaps the sound emitted when the fruit is thumped with the finger is the most reliable way of determining the stage of ripeness of watermelons. Most varieties give forth a metallic, ringing sound when they are green and a more muffled or dead sound as they become more mature. The greener the melon, the more metallic the sound. The sound is not the same for all varieties so that some should be pulled when they still give forth a somewhat metallic sound, while others should be left on the vines until the sound is quite a dead one. It is only by experience that one becomes able to select the ripe fruits, but with precaution and by cutting a melon occasionally the knack is readily acquired. The fruit is pulled or cut from the vine with about 2 inches of stem; this is very important since by applying a disinfectant to the stem the stem-end rot can be prevented from developing in transit.

Grading.—Watermelons usually are not separated into grades, although the U. S. Department of Agriculture has worked out specifications for two grades, U. S. No. 1 and U. S. No. 2, and unclassified. These grades require that melons be mature, but not overripe, well formed and free from disease, insect, and other injury. Size may be stated in terms of average or minimum weight. Most markets prefer medium-sized melons, but the Pacific coast markets prefer small ones. The price usually varies with the size,—the larger the size, the higher the price.

Handling.—After the watermelons are pulled and placed in rows in the field they are usually loaded on wagons or trucks and hauled direct to local markets, or to cars when they are to be shipped. Most of those shipped are loaded four deep in box cars and in some cases, in cattle cars. The cars are usually cleaned, then a layer of clean straw is placed on the floor. The number of melons loaded in a car varies from 800 to 1,500 depending on their size. When the fruits average 35 pounds in weight and are loaded four deep, a car 34 feet long will carry 800. If the average weight is 25 pounds, the car loaded in the same way will contain about 1,100 melons.

For express shipments very early in the season, watermelons are sometimes packed in barrels, using excelsior, straw, or other litter as packing material. This method of packing is used to a very limited extent.

PUMPKIN AND SQUASH

These two crops are discussed together because their cultural requirements are similar and because there is so much confusion in regard to important species.

While these crops are not of great commercial importance they are of great interest and are grown in a small way by many home gardeners, by market gardeners and by special growers.

History and Taxonomy.—There is still considerable difference of opinion as to the nativity of pumpkins and squashes. Some botanists believe that all of them are of American origin and others believe that *Cucurbita pepo* and *C. moschata* are of American and that *C. maxima* is of Asiatic origin. According to Erwin (1930) there is good evidence that *C. pepo* and *C. moschata* are of American origin. Archeologists have found fragments of the rind, peduncles, and seeds in the ruins of the Cliff Dwellers in excellent state of preservation. The taxonomic characters of these, according to Erwin, are clearly defined. Erwin states that he studied material in the Peabody Museum of Harvard University and in the Colorado State Historical Museum and found numerous specimens of *C. moschata* and *C. pepo*. "In the instance of the Peabody collection, some specimens are quite ancient. According to Kidder they are from the Basket Makers, a culture antedating the Cliff Dwellers, and are regarded by him as belonging to the period 1500 to 2000 B.C."

Erwin also mentions material collected by Neil M. Judd at Pueblo Bonito, N. M., fragments of stems and seeds identified as *C. pepo* and *C. moschata*. Plants of *C. moschata* are found growing wild in the Florida Everglades and other plants resembling *C. pepo* have been found growing wild in Texas. The evidence seems clear that the pumpkins are of American origin and it is not at all improbable that the squashes *C. maxima* are also indigenous to America.

Much confusion exists in the horticultural literature as to the use of the terms pumpkin and squash, but present-day students of this group of plants, belonging to three species of cucurbita, are agreed in general on the nomenclature. Thus Bailey (1929) and Castetter and Erwin (1927) call all types and varieties of *C. pepo* and *C. moschata* pumpkins, and all types and varieties of *C. maxima* they call squash. Thus the term pumpkin includes such divergent forms as the small bush varieties such as White Bush Scallop, Early Yellow Bush Scallop, and others, and the long-vine, large-fruited varieties, such as Connecticut Field, Large Cheese, Striped Cushaw, and Mammoth Golden Cushaw. The last three belong to *C. moschata* and the others belong to *C. pepo*. In the popular horticultural literature the bush varieties and the cushaws have been called squash and the Connecticut Field has been called pumpkin.

However, it seems best to follow the terminology of Bailey and of Castetter and Erwin, since the species can be easily separated by means of a simple key giving the foliage, fruit stalk, and seed characters. The following key to the annual cultivated species of cucurbita was published by Castetter and Erwin after several years of painstaking and careful study:

(*A*) Leaves

- 1. Prickly, deep sinuses between lobes.......................... *C. pepo.*
- 2. Not prickly, sinuses indistinct or absent.
  - (*a*) Lobes pointed, with rare exceptions leaves soft, hairy with white spots at intersections of veins..................... *C. moschata.*
  - (*b*) Lobes rounded; rough hairy, kidney shaped, white spots never present.. *C. maxima.*

(*B*) Fruit stalks

- 1. Cylindrical, soft and spongy, yielding readily to the thumbnail. . *C. maxima.*
- 2. Distinctly five sided, regularly grooved, hard.
  - (*a*) Flaring at attachment to fruit.......................... *C. moschata.*
  - (*b*) Not noticeably flaring or enlarged at attachment to fruit. . . *C. pepo.*
- 3. Roughly cylindrical, not definitely five sided, irregularly grooved, not flaring or noticeably enlarged at attachment to fruit, hard. . *C. moschata.*

(*C*) Seeds

- 1. Color, grayish white to tan; margin thickened, deeper in color and different in texture from body of seed; seed scar slanting, rounded or horizontal... *C. moschata.*
- 2. Margin, when present, identical in color and texture with body of seed.
  - (*a*) White, or brown to bronze, seed scar slanting............ *C. maxima.*
  - (*b*) Tan colored, seed scar horizontal or rounded............. *C. pepo.*

Culture.—The general requirements of the pumpkin and of the squash are not very different from the other cucurbits. They do not require so long a growing season as the watermelon and muskmelon and for this reason they can be, and are, grown in nearly all parts of the United States and in many of the provinces of Canada. While the plants are not so tender as melon plants they are injured by frost, so that planting should be delayed until the weather has settled and the ground has become warm.

Any good type of well-drained soil will produce satisfactory crops of pumpkins and squashes if other conditions are favorable. They are often grown on heavier soil than is considered safe for melons in the North.

In many sections, winter pumpkins and squashes are grown as a companion crop to corn. When so grown, they require no cultivation and care except that given the corn.

The time and method of planting squashes and pumpkins are about the same as for the other cucurbits. They are sometimes started in hotbeds and greenhouses, but this is not common. Bush pumpkins are planted in hills about 4 by 4 or 4 by 5 feet, or in rows 4 to 5 feet apart. In the latter method, the seeds are sown thickly and the plants thinned to stand about 3 feet apart in the row. The running varieties of squashes and pumpkins are planted either in hills, or in drills. When planted in hills, the spacing varies from 8 by 8 to 12 by 12 feet depending on the fertility of the soil and the vigor of the varieties. In the drill method, the seeds are sown in the row and the plants thinned to stand 3 to 4 feet apart.

The same cultivation and care are suggested as for the other cucurbits.

Varieties.—American seed catalogs list a large number of varieties of pumpkins and squashes. The readiness with which the varieties within a given species cross lead to the constant appearance of new strains and varieties. Not many of those listed are of great importance. Castetter and Erwin (1927) have grouped 40 varieties of pumpkins into seven groups: five of these belonging to *C. pepo* and two to *C. moschata*. Two varieties, Mandan and Chirimen, they did not place in any of the seven groups. The 28 varieties of squashes were put into four groups, and one variety, Faxon's Brazilian, was not placed with any group. The groups are as follows:

1. CONNECTICUT FIELD GROUP (*C. pepo*).—Fruits are either round with flattened ends, or oblong; surface grooved. This group includes some of the best known pie varieties, a few being grown primarily for stock food. Vines are of running habit. The varieties belonging to this group are Connecticut Field, Sugar Pumpkin, Pie Pumpkin, Fort Berthold, Golden Oblong, Mammoth Tours, Omaha, and Sandwich Island.

2. CHEESE GROUP (*C. moschata*).—Smooth, creamy buff, thin-shelled fruits of various shapes. All varieties have running vines. The varieties belonging to this group are Calhoun, French Cocoanut, Large Cheese, and Quaker Pie.

3. CUSHAW GROUP (*C. moschata*).—Plants of the running type. Fruits smooth, with curved or straight neck and much enlarged at blossom end. With the exception of the Tennessee Sweet Potato they have thin rind. The varieties of this group are Japanese Pie, Mammoth Golden Cushaw, Small Golden Cushaw, Striped Cushaw, Tennessee Sweet Potato, and White Cushaw.

4. FORDHOOK GROUP (*C. pepo*).—Rather small fruits, quite variable in shape, but all characterized by distinct grooves and ridges. This group embraces both summer and winter pumpkins, also bush and running plants. This group includes Delicata, Fordhook Bush, Fordhook, Panama, Perfect Gem, Table Queen, and Winter Nut.

5. PATTY PAN GROUP (*C. pepo*).—Fruits flat, edge scalloped. Summer pumpkins of the bush type. The varieties in this group have been known as squashes. In this group are the following varieties: Early White Bush Scallop, Early Yellow Bush Scallop, Golden Custard, Mammoth White Bush Scallop, and Long Island White Bush Scallop.

6. CROOKNECK GROUP (*C. pepo*).—Fruits golden yellow or white, thickly warted and with long curved necks. These are summer pumpkins and the varieties include White Summer Crookneck, Yellow Summer Crookneck, and Strickler. While this

group is called Crookneck, there are strains of the variety Yellow Summer Crookneck that have straight-neck fruits.

7. Vegetable Marrow Group (*C. pepo*).—Fruit oblong, skin smooth, shell hard at maturity, ranging in color from cream to dark green. Plants both bush and running in habit. The varieties in this group include Cocozelle, Long White Marrow, Vining Cocozelle, White Vining Vegetable Marrow, and Zucchini.

The varieties of squashes, *C. maxima*, are grouped into the following four groups by Castetter and Erwin:

1. Banana Group.—Fruits elongated and somewhat tapering at both ends. The varieties in this group are Banana, Alligator, Gilmore, Mammoth Whale, Plymouth Rock, and Winnebago.
2. Hubbard Group.—Fruits of a general ovoid shape and always pointed at the blossom end. Surface varies from smooth to strongly warted; in color ranges from deep green to orange. This is the most important group of squashes and includes the following varieties: Centennial Marrow, Blue Hubbard, Chicago Warted Hubbard, Delicious, Golden Delicious, Golden Hubbard, Green Hubbard, Ironclad, Kitchenette Hubbard, Marblehead, Prolific Marrow, and Sibley.
3. Turban Group.—Fruits turban shaped, usually with a button at the blossom end. With the exception of the American Turban, the thick, hard shell of the fruits makes this a group of good keepers. The varieties include American Turban, Essex Hybrid, Bay State, Victor, and Warren.
4. Mammoth Group.—Fruits large and are often used for exhibition purposes, for canning, and for stock feed. Some specimens weigh 100 pounds. The varieties are Atlas, Estampes, Genuine Mammoth, and Mammoth Chili.

The most popular varieties of summer pumpkins (*C. pepo*), commonly called summer squashes, are White Bush Scallop of which there are several distinct strains, Straightneck, Cocozelle, and Zucchini. Of the winter pumpkins, the Winter Luxury, New England Pie, and Connecticut Field are perhaps the most popular. Of the winter squashes, the most popular are the Hubbard group, including Hubbard or Green Hubbard, Blue Hubbard and Golden Hubbard, Boston Marrow, Quality, Golden Delicious, and Table Queen (Acorn). The last is a small-fruited variety, popular for baking and serving in the shell.

Diseases.—Pumpkins and squashes ordinarily are not seriously injured by disease, although they are attacked by downy mildew, bacterial wilt, and anthracnose. For a discussion of the first two see "Cucumber," and for anthracnose see "Watermelon."

Insects.—The most important insect pests of these crops are the squash bug and the squash-vine borer. Both of these seem to prefer the pumpkin and squash vines to the other cucurbits and are often very destructive. Some of the other insects discussed under cucumber also attack these crops. See discussion of insects under cucumber.

Harvesting.—Bush pumpkins are harvested as soon as the fruits are of edible size and before the rind begins to harden. The simplest test to determine when the summer pumpkin is too old is the use of the thumbnail. When the rind becomes somewhat resistant to the pressure of the thumbnail it is too old to be used for food and should not be marketed. This test is of no value for the other types. High quality of winter squashes and pumpkins is generally associated with maturity, so that they should not be harvested until they are fully ripe, but before they have been frosted.

Both pumpkins and squashes are pulled or cut from the vine with a portion of the stem attached to the fruit. This is desirable since the removal of the stem would leave a large scar through which decay organisms could easily enter.

Careful handling, from the time they are harvested until they are finally disposed of, is important since fruits bruised or otherwise injured decay much more rapidly than uninjured ones. Any breaking of the skin is usually followed by decay.

Grading and Packing.—Pumpkins and squashes are seldom graded to any particular specifications, but when the small, summer pumpkins are packed in containers for shipment some grading is done. As a rule, fruits are selected for uniformity in size, shape, and color; those that are injured or are overmature are discarded. Even with the winter pumpkins and squashes some grading is done, especially to separate the sizes. Most markets prefer the small to medium fruits, while canners and bakers prefer the large ones.

Small, summer pumpkins are packed for shipment in various kinds of containers including baskets, barrels, boxes, and crates. The larger fruits, especially the winter varieties of pumpkins and squashes, are usually handled in bulk. The smaller fruits are sometimes put up in bags or in barrels.

Storage.—Squashes and pumpkins can be kept for several months if they are in good condition at the time of storage and are kept at the proper temperature and humidity. The conditions necessary to keep these crops are very different from those necessary to keep root crops.

After the fruits are harvested they should undergo a ripening or curing process to harden the shell. This can be done by leaving them in small piles in the field when the weather is dry and warm; a better method is to place them in storage and to use artificial heat and thorough ventilation.

Most authorities agree that pumpkins and squashes keep best at relatively high storage temperature; temperatures between 50° and 60°F. have been recommended. Cummings and Jenkins (1925) have reported results which indicate that lower temperatures, 42° to 50° or 52°F., are better than higher temperatures. The weight loss is greater at high than at low temperature, due to loss of moisture and of carbohydrates. Cummings and Jenkins suggest that the losses in weight are due to loss of carbohydrates since the moisture and protein determinations indicate an increase in percentage of these two, but it should be noted that the total loss in weight exceeded the total dry matter. The loss in weight could not be accounted for by loss of carbohydrates since the total carbohydrate content in the beginning was less than the weight loss for the storage period. The dry-matter content at harvest time averaged about 15 per cent and the weight loss for the first 4 months sometimes exceeded this. The loss was mainly water, but this was masked by the loss in dry matter due to respiration and the water formed in the same process.

Stuart (1907) reported a storage test of Hubbard squash stored in a dry, medium warm room (50° to 60°F.) in which the loss by shrinkage was 20.8 per cent and by decay 4.8 per cent, making a total loss of 25.6 per cent in 4 months. Cummings and Jennings have shown that the losses are increased as the temperature is raised above 50°F.

Results of more recent experiments reported by Platenius, Jamison, and Thompson (1934) indicate that squashes can be kept for five months at 40°F. and a relative humidity below 70 per cent. At this temperature and at relative humidities between 50 and 70 per cent, the shrinkage was less than 3 per cent per month and the conversion of starch to sugar proceeded much more slowly than at a higher temperature. After five months storage under the conditions mentioned, the squashes were in excellent condition. In these experiments, storage at 60° to 70°F. and a humidity of 60 per cent or less resulted in very high shrinkage—more than 7 per cent a month. In addition, a very rapid conversion of starch to sugar took place under these conditions.

Cold-storage rooms are unsuited to the storage of squash because of the very high humidity that prevails.

CHAYOTE

The chayote (*Sechium edule*) belongs to the family cucurbitaceae and is said to be indigenous to Mexico, Central America, and the West Indies. It is of ancient cultivation in Central America. The plant is a perennial-rooted vine that bears large crops of edible fruits (Fig. 66 and 67). In subtropical regions the plant produces large edible tubers. According to Hoover (1923), the chayote is an important food plant in parts of Mexico and Central America, "where it occupies fully as important a place as does the potato in more northern latitudes."

Experiments conducted by the U. S. Department of Agriculture have demonstrated that the chayote is adapted to the mild-wintered regions of the South Atlantic and Gulf coast states. Hoover states that it has been grown for more than a generation in certain restricted areas of the South, notably in the region of New Orleans, La.; Savannah, Ga.; and

Charleston and Columbia, S. C. In these regions it has been known under the names of vegetable pear, mirliton, and mango squash.

The fruits vary in color from dark green to ivory white. The size ranges from a few ounces to 2 pounds or more in weight. According to Hoover, an ideal fruit for market weighs from 8 ounces to a pound or more, has a smooth surface, fiber-free flesh, and a delicate agreeable flavor. A number of types have been developed, whose fruits may be grouped according to color, size, surface, form, and quality. Some types are deeply wrinkled or corrugated, others smooth. In quality they vary from fiberless with no pronounced seed coat surrounding the single flat seed to those having a tough, fibrous inedible seed coat with fibers radiating into the flesh.

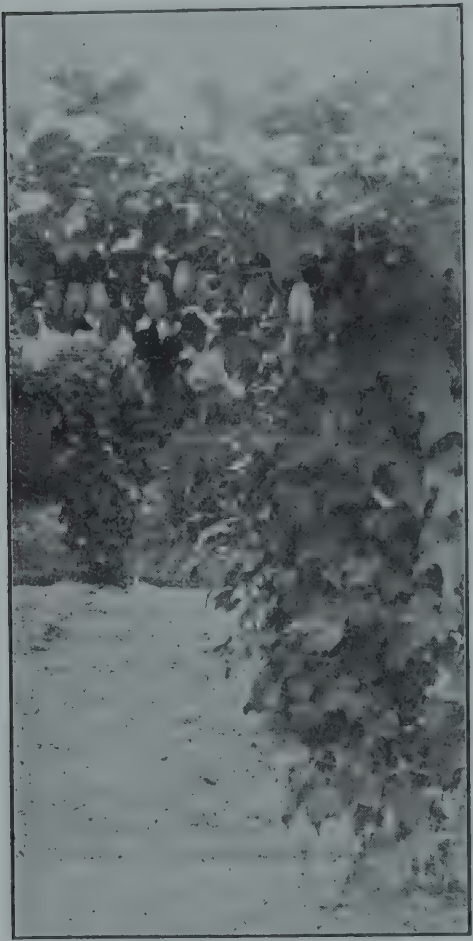

Fig. 66.—Chayote plant grown on trellis. (*Courtesy of U. S. Dept. Agr.*)

One plant well cared for will produce enough fruit for the family of average size.

Culture.—As an annual, the chayote can be grown as far north as Washington, D. C., but as a perennial it does not succeed farther north than Charleston, S. C., on the Atlantic coast. Freezing kills the entire plant. It is adapted to culture in regions where the ground does not freeze more than an inch or two.

Chayotes grow best on a rich, well-drained, sandy-loam soil, but will produce a crop on ordinary loams and on good, well-drained mucks. The entire fruit is planted, one in a hill in rows 12 feet apart. It is planted on the side with the broad end sloping slightly downward and the smaller or stem end slightly exposed. The chayote does not always come true from seed; for this reason it is sometimes propagated by vegetative cuttings. Young shoots are removed with a sharp knife, close to the crown of the plant and while they show solid tissue throughout. The cuttings are rooted in sharp sand and then are potted and grown under protection until time for planting outside. In transplanting to the field, care should be exercised to prevent injuring the roots.

The chayote is a vigorous grower and produces a large quantity of fruit, and must be well fertilized. Well-rotted manure gives good results but should be supplemented with fertilizer. Hoover recommends fertilizer at intervals as the plants need it.

The plants are supported on trellises or other supports. A fence may be used or they may be supported on large T trellises, covered with heavy 4-inch mesh, fencing wire.

Where the chayote is grown as a perennial, a mulch should be applied to protect the roots from freezing. The mulch should be loose but fairly thick. Straw, hay, weeds, or similar material is satisfactory.

The chayote is attacked by the pickleworm, the squash ladybird, and both the striped and spotted cucumber beetle. These have been discussed under cucumber.

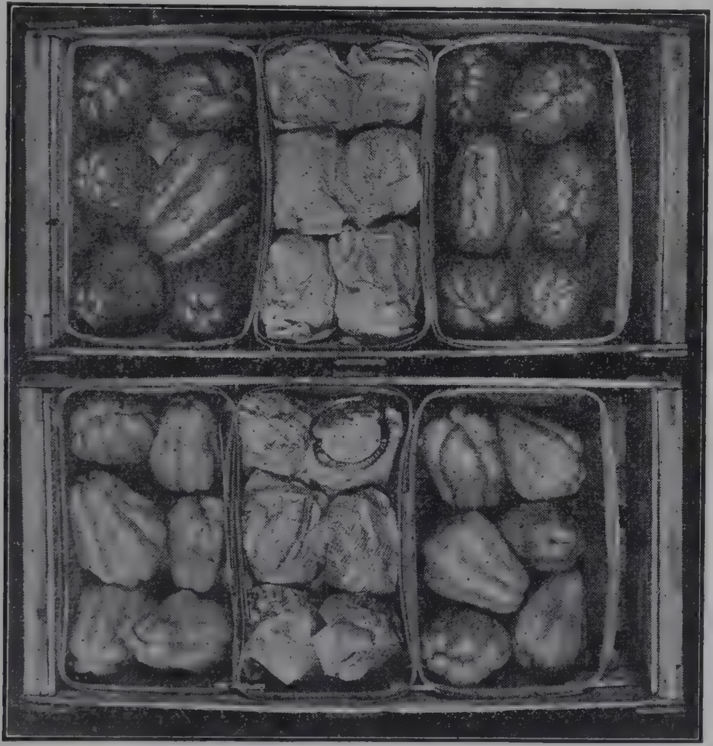

FIG. 67.—Chayote fruits packed for market. (*Courtesy of U. S. Dept. Agr.*)

The root nematode is also serious in many regions. Other diseases are sometimes injurious.

Uses of the Chayote.—The fruit is the part of the plant that is generally prized in the United States, although other parts have various uses. The foliage is eaten readily by cattle; the plant is used to some extent as an ornamental vine on porches or trellises, and the tubers are used as food in the tropics.

The fruit is prepared for the table in various ways. It is often cut into thick slices, pared, and boiled until tender and served with butter; or the boiled slices may be served with cream sauce. The fruits are sometimes baked with cheese, made into a salad, and pickled.

CHAPTER XXVII

SWEET CORN, OKRA, MARTYNIA

These three crops are placed together because none of them fits into the other groups, and not on account of any special similarity. They are, however, all warm-season annuals, are tender to frost, and are grown for their fruits. Only one, sweet corn, is of any great commercial importance in the United States. Sweet corn is of greatest importance in the North; okra is produced mainly in the South; and martynia is grown to a limited extent only, largely as a curiosity.

SWEET CORN

While the sweet-corn plant is tender to frost and grows best in hot weather, the main areas of commercial production in the United States are in the northern states. The crop is also grown in portions of Canada. It is not an important commercial crop in any state south of Maryland. This is due probably to the serious injury done by the corn earworm in the South and to high temperatures at harvest time. At high temperatures the corn matures very rapidly and it is difficult to harvest the ears at just the right time; if this is not done a loss results. After the ears are pulled from the stalk there is a rapid deterioration in quality due to the loss of sugar, the higher the temperature the more rapid the change. These factors give the cooler regions a decided advantage over the South in sweet-corn production.

Since sweet corn is harvested for use before it begins to harden, its production is not limited by climatic conditions to the same extent as is field corn for grain. Sweet corn is a very successful crop in many regions of the North where field corn for grain cannot be produced in normal seasons.

Sweet corn is shipped to a very limited extent only, because of the rapid deterioration in quality; hence most of the crop consumed in the fresh state is produced in the home garden and in market gardens. A very large percentage of the crop is grown for canning.

Statistics of Production.—According to the report of the Bureau of the Census, the acreage of sweet corn was 483,053 acres in 1929 and the gross value was $21,928,856. This includes sweet corn grown for market as well as that grown for manufacture. The estimated acreage, production, and value of sweet corn grown for manufacture, as reported by the U. S.

Department of Agriculture (*Agricultural Statistics*, 1938), is given in Table LXXI.

TABLE LXXI.—ESTIMATED AVERAGE ANNUAL ACREAGE, PRODUCTION, AND VALUE OF SWEET CORN GROWN FOR MANUFACTURE BY 5-YEAR PERIODS, 1918 TO 1937

Years	Acres	Yield, tons per acre	Production in tons	Price per ton	Value (000 omitted)
1918–1922	224,158	2.28	510,820	$16.30	$8,325
1923–1927	297,990	2.27	675,420	13.64	9,214
1928–1932	313,950	2.00	628,020	11.83	7,431
1932–1937	338,266	1.96	662,360	9.86	6,534

In 1937, the leading states in acreage of sweet corn grown for manufacture were Illinois with 89,400 acres; Minnesota with 72,100 acres; Iowa with 54,300 acres; Indiana with 51,400 acres; Maryland with 37,600 acres; Wisconsin with 24,300 acres; Ohio with 22,000 acres, New York with 21,400 acres; and Maine with 18,200 acres. In total production the order was Illinois, Minnesota, Iowa, Indiana, Maryland, Maine, Ohio, Wisconsin, and New York.

Estimates of the acreage, production, and value of sweet corn grown for market in fresh condition are published only for New Jersey, which in 1937 produced 24,000 acres valued at $1,440,000. Carlot shipments were reported from 10 of the southern states in 1937. Most of the northern states produce sweet corn for near-by markets; in some it is an important crop.

Influence of Climate.—Reference has been made to the effect of hot weather on the rapid maturity of sweet corn and also on the injury caused by the corn earworm. There has been a widespread belief that sweet corn canned near the northern limit of its production is sweeter and of better quality than that canned farther south. Experimental evidence shows quite conclusively that this is true, but the belief that sweet corn develops a higher sugar content in the North than in the South is not borne out by experimental data. Straughn (1907) has reported analyses of sweet corn grown at Clemson College, S. C.; College Park, Md.; New Brunswick, N. J.; New Haven, Conn., and Orono, Maine. The data reported represent from 20 to 100 analyses of each variety at each station. The highest percentage of sugar in both the Crosby and Stowell's Evergreen was in the corn grown in South Carolina and the lowest in Connecticut.

Later, Straughn and Church (1909) reported on results secured during 4 years, 1905 to 1908, for the Crosby and Stowell's Evergreen varieties grown in Florida, South Carolina, Maryland, Connecticut, and Maine. In this work, the seed used at all the stations was the same strain and the analyses were made at the stations where the corn was grown. Their results failed to show any direct relation between latitude in which the corn was grown and the sugar content. Three years out of four the corn grown in South Carolina had the highest sugar content and in the other year there was very little difference between the three highest. Connecticut-grown corn had the lowest percentage of sugar, while that from Maine and Maryland was intermediate and about equal.

The advantages of northern-canned corn are apparently not due to the difference in sugar content at time of harvest, but rather to the temperature prevailing at harvest time. Appleman and Arthur (1919) have shown that the temperature to which the corn is subjected after being pulled from the stalk influences the rate of sugar loss, the higher the temperature the more rapid the loss. (See p. 543.) Stevens and Higgins (1919) have shown that the temperature prevailing during harvest in Maryland is considerably higher than that in Maine. They state that corn canning in Maryland falls largely in August, while in Maine it is mainly in September. The mean temperature for Baltimore, Md., from Aug. 2 to 31 is 74.6°F. and at Portland, Maine, the mean temperature for September is 59.5°. The bulk of the corn canned in Maryland is harvested in August and a large part of the Maine corn is harvested in September. The highest mean temperature at Portland, Maine, 62.6°F. is 6 degrees below the lowest mean for Baltimore, 68.6°.

Culpepper and Magoon (1926) have shown that seasonal factors have a marked effect on rate of development, and through this on quality of sweet corn. For example, the number of days from planting to silking of Golden Bantam varied from 55 to 79 days, and Stowell's Evergreen from 63 to 92 days. The most important factor involved is temperature: the higher the temperature the more rapid the rate of development.

TABLE LXXII.—CALCULATED RATE OF SWEET CORN RIPENING FOR MEAN TEMPERATURES 60° TO 80°F.
(After Appleman)

Average of daily mean, ° F.	Time required to pass from pre-milk to best canning stage	The canning period in days
60	14.5	5
65	12.0	4
70	10.0	3
75	8.0	3
80	7.0	2
85	5.5	1.5

Similar results have been reported by Appleman (1923), as is shown in Table LXXII.

History and Taxonomy.—Sweet corn is probably of very recent origin, since it was not mentioned by Jefferson in his *Notes on Virginia*, 1781, nor by McMahon, 1806. A writer in the *New England Farmer*, August 3, 1822, states that sweet corn was not known in New England until a gentleman from Plymouth, who was in General Sullivan's expedition against the Indians in 1779 brought back a few ears which he found among the Indians on the border of the Susquehanna. Another writer in September, 1822, asserts that this sweet corn was brought back by Lieutenant Richard Bagnal from General Sullivan's expedition against the Six Nations in 1779 and was called *papoon corn.* In 1832 sweet corn was mentioned by Bridgeman.[1] After 1850 it was frequently mentioned by writers. In 1851, Buist[2] mentions two varieties; in 1854, Schenck mentions three varieties as having been brought into notice within a few months; in 1866, Burr describes 12 varieties.

The word *corn* has a special meaning in the United States and is applied only to Indian corn or maize while in other countries it applies to all bread grains. In Europe, the word "corn" applies to oats, wheat, rye, or barley, as well as to Indian corn. The references to corn in the Bible probably mean only the small grains since Indian corn or maize was not known in the Eastern Hemisphere prior to the discovery of America.

Corn or Indian corn was probably grown by the natives of the Americas from a very ancient date. Plumb (1895) writes that

> mounds that were erected prior to the time of the American Indian, of which he has no tradition, that have been explored in recent years, have contained corn cobs and charred kernels. In the caves, occupied by the early Cliff Dwellers in the southwestern states ears of corn have frequently been discovered. In South America, Darwin found on the coast of Peru heads of maize, together with eighteen species of recent sea shells embedded in a beach which had been upraised at least 85 feet above the level of the sea. Ears of Indian corn are occasionally found in vessels placed in ancient Indian tombs or mounds in Chile, Peru, and Central America.

The early explorers of this country found the Indians growing corn from Canada to Florida. They taught the early settlers how to grow it. In fact, it was the leading crop among the natives of this continent at the time of the discovery of America.

Authorities generally agree that corn is probably a native of Mexico. Harshberger (1913) states that "all plants closely related to maize are

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[1] *Gard. Asst.*, 1832.

[2] *Family Kitchen Garden*, 61, 1851.

Mexican. The evidence to the present date (1893) places the original home of our American cereal maize in Central Mexico."

Sweet corn and field corn belong to the grass family and to the genus *Zea*. These two are considered by most authorities as belonging to the same species, *Zea Mays* Linn.; sweet corn is designated by the variety name *rugosa*. It is distinguished from other corns by its high sugar content when in the milk and early dough stage, and by its wrinkled translucent kernels when dry.

Soil Preference.—Sweet corn, like field corn, can be grown on a great variety of soils. Where earliness is an important factor, as in its production for a local market, a well-drained sandy-loam soil is considered best since such a soil warms up early in the spring and usually matures a crop before drought occurs. Such a soil, if supplied with humus and well fertilized, will produce a good yield even during the drier part of the season. In growing sweet corn for the canning factory, a large yield is more important than earliness, therefore, a rich, retentive soil is desired. Silts, silt loams, and clay loams are better than the sandy and sandy-loam soils for the canning crop. In many regions, as in the Genesee Valley of New York and the Scioto Valley of Ohio, rich river bottom lands are used extensively. These soils are not only rich in mineral nutrients but less subject to drought than most other soils. Such soils are enriched by the deposit of sediment during periods of flood. Muck soil has been used to advantage in the production of sweet corn. Frost usually occurs later in spring and earlier in fall on these soils than on the surrounding uplands, but in nearly all regions where field corn can be grown for grain on upland soils the growing season on the muck is long enough to produce a crop of sweet corn. These soils in the upper part of the corn belt are not satisfactory for field corn for grain on account of the late frosts in spring and early frosts in fall.

Manures and Fertilizers.—While sweet corn is a heavy feeder it is not usual to fertilize very heavily, except in growing early corn for market on the lighter soils. Under such conditions, fairly heavy fertilization is frequently given. Comin and Bushnell (1928) have shown that manure at $3.75 per ton was not profitable in growing sweet corn on an alluvial soil at Marietta, Ohio. Nitrogen gave the most significant increase in yields in these experiments.

When sweet corn is grown on rich soil or when it is grown in rotation with general farm crops and manure is used in the rotation, many growers apply no fertilizer or only a light application of superphosphate. This method is satisfactory under the conditions mentioned, but in most cases it is desirable to apply a complete fertilizer on light soils and on the poorer silt loams and clay loams. On sandy and sandy-loam soils, with little or no manure, the fertilizer application should supply from

20 to 50 pounds of nitrogen and 40 to 100 pounds each of phosphoric acid and potash. The actual quantities should be determined by the fertility of the soil and the returns that might be expected from the crop. On silt loams and clay loams of fair fertility, 10 to 25 pounds of nitrogen, 40 to 80 pounds of phosphoric acid, and 10 to 25 pounds of potash should give good results. Sweet corn for an early market requires some readily available nitrogen; on light soils it may be advisable to supply additional nitrogen during the growth of the crop.

Difference of opinion exists as to whether it is better to apply the fertilizer in the hill or broadcast. Some writers have asserted that when the fertilizer is applied in the hill corn suffers more from drought. This has been explained as being due to a smaller root system where hill application is practiced. There is no evidence that the location of the fertilizer in the hill has any tendency to restrict the root system. Millar (1922) has reported results of experiments with corn in Michigan in which a comparison of hill and broadcast applications was made. The soil on which this experiment was conducted is a dark sandy loam resting on a heavy clay subsoil. The hills were placed 44 inches apart each way and the variety of corn was Golden Glow. A complete fertilizer having the composition 3–10–4 was used, and the hill application was at the rate of 200 pounds to the acre. This was sprinkled over an area about 8 inches long and 4 to 5 inches wide in the bottom of the hill and covered with about one-half inch of soil before dropping the seed. For comparison 400 pounds of the same fertilizer were applied broadcast on one portion of the field and this was mixed with soil before the corn was planted. At the end of 30 days the corn fertilized with 200 pounds of the mixture applied in the hill was much larger than that on the broadcast treatment. The root systems were dug out in order to show the effect of the method of fertilizer application on the extent of the root growth. The author states that there was little, if any, difference in the extent of the root growth and that the application of the fertilizer under the seed did not lead to a concentration of roots in this zone. A second examination was made 57 days after planting; at this time the corn fertilized in the hill was in full tassel and in the early silk stage while that fertilized broadcast was just coming into tassel. The root systems were well distributed throughout the soil in both cases.

Experiments by Truog *et al.* (1925) in Wisconsin indicate that hill application of fertilizer for corn is preferable to other methods when only a small quantity is used. They state that applications up to 200 pounds of 2–12–2 and similar analyses are safe, except on sandy soils. If the fertilizers are drilled in the row the application might be increased to 300 or 400 pounds. The best method of hill application is in a band 4 inches wide and 8 inches long from ½ to ¾ inch above the seed, never in contact with the seed. They found no indication that hill fertilization restricts root growth.

Smith (1927) found that germination and root growth were retarded when fertilizer was applied with the seed. He states that the desirable effects of fertilizers on the early growth, maturity, and yield appeared to be in proportion to the development of the roots.

Results of many recent experiments with field corn show that application of fertilizer in bands to the side of the row is preferable to application in the row. These results also indicate that band application is better than broadcast application, especially where a relatively small quantity of fertilizer is used. In some cases, an application of 200 to 300 pounds of fertilizer of normal concentration in bands has given as good results as a much larger quantity applied broadcast. Where heavy applications are used, it might be best to apply part of the fertilizer broadcast and part in bands a few inches from the row and about on the level with the seed.

Planting.—Sweet corn is injured by frost, hence it is not safe to plant until the danger of hard frosts is over. It is worth while, however, to take chances on frosts where the crop is grown for a local market in which early corn brings high prices. As a rule, it is safe to plant sweet corn about the time of the last killing frost in spring. In order to have sweet corn available from the time the earliest varieties are ready for use until frost in autumn, it is necessary to make several plantings, or else to plant early, medium, and late varieties at about the same time. One practice is to make a planting of an early variety as early in the spring as the conditions will allow. In 2 or 3 weeks another planting is made of the same or a similar variety; at the same time a medium and a late variety are planted. Another practice is to make several plantings of one variety, usually an early one at intervals of 2 or 3 weeks, the last planting being made at such a time that it will be ready for use just before frost in the autumn. The time that this last planting should be made depends on the variety used and the locality.

For a very early crop the plants may be started in the greenhouse or hotbed 3 or 4 weeks before time for planting in the field. Seeds are planted in plant bands, pots, or other receptacles, several seeds to each receptacle. In setting the plants in the field or garden, care must be taken not to disturb the roots. After the plants have become established, they are thinned to the desired number in each hill. This method of growing plants is practicable only for home use and for a special market. The planting distance for sweet corn depends on the variety grown, since the larger the variety the more space required. Both drill and hill methods of planting are practiced and there exists considerable difference of opinion as to which is the better. With the hill method, cultivation can be given in both directions and this reduces the amount of hand work required. On the other hand, the drill method gives a better distribution of plants and very often a larger yield. When the hill method is employed six to eight seeds are planted and the plants are thinned to three or four to the hill. The hills are spaced 2 by 2½ or 2 by 3 feet apart for the small-growing varieties and 2½ by 3, 3 by 3, or 3½ by 3½ feet for the large-growing varieties. In the drill method the seeds are distributed singly and the plants are thinned to stand 8 to 12 inches apart in the row, the distance depending largely on the variety.

Planting is done either by hand or by means of a horse-drawn planter. When planted by hand the kernels may be dropped into a shallow furrow, or a hand planter may be used. The hand planter is a great labor saver and is used quite largely by market gardeners in many regions. Machine planters are made to plant either one or two rows at a time. These machines open the furrow, drop the corn, and cover it all at one operation. For small acreages the large machines are not justified, but for large acreages they may be economical.

Experimental results reported by Hoffman (1925) have shown that large kernels give an earlier and larger yield of sweet corn than small kernels of the same stock. Plants from the large kernels reached tasseling, full-silk, and canning stage about 5 days before those from small kernels. There were fewer barren stalks from the plants grown from large seed than from those grown from small seed. In growing sweet corn for canning, it is desirable to grade the seed and plant the large and small kernels separately so as to have more uniform maturity. This is a great advantage because all the ears from a given lot can be harvested at one picking. Because of less variation in maturity, the quality of the corn is likely to be better from graded than from ungraded seed. Results obtained by Sayre (1928) in New York are similar to those reported by Hoffman in Indiana.

Cultivation.—The cultivation of sweet corn is about the same as that given field corn. Many growers follow the practice of running a weeder, or a spike-tooth harrow, over the field before the corn comes up and sometimes after it is up. This is a good practice as the breaking of the surface destroys the weeds and gives the corn a chance to get started ahead of them. Even after the corn comes up, the weeder or harrow can be used to good advantage as the surface is loosened and the weeds are destroyed between the plants in the row as well as between the rows, whereas with a cultivator only the space between the rows is cultivated. The use of the weeder or harrow eliminates some of the hand work. After the plants are 3 to 4 inches high a cultivator is used in place of the weeder and the cultivation is confined to the space between the rows. Both one- and two-horse cultivators are used, the former on small areas and the latter where sweet corn is grown on a large scale. Most of the growers for canning factories in New York use a two-horse cultivator.

Some authorities advocate deep cultivation while the plants are small, and shallow cultivation later when the roots extend a considerable distance from the plants. If, however, the land has been well prepared there is no point to deep cultivation at any time, and the turning up of the moist soil increases the water loss by evaporation. Thorough preparation of the seedbed and shallow cultivation make a good combination. Only shallow cultivation should be given after the roots extend across the rows for deep cultivation results in destruction of many roots.

Results of experiments in the cultivation of field corn, carried on by many experiment stations and by the U. S. Department of Agriculture have shown conclusively that destruction of weeds is the main object to be accomplished in cultivation. Cates and Cox (1912) have reported on a series of cooperative experiments carried on in 28 states and covering a 5-year period, 1907 to 1912. In all, 124 experiments were conducted and the average yield of the uncultivated plots was 99.108 per cent of the yield from the cultivated ones. In the uncultivated plots, the weeds were kept down by cutting them off at the surface of the soil without forming a mulch. They found no correlation between the rainfall and the comparative values of cultivation and no cultivation.

Mosier and Gustafson (1915) grouped the experiments of Cates and Cox according to soil type and found a slight correlation. On clay soils the average yields of the uncultivated plots was 92.6 per cent of that of the cultivated ones, clay loams 94.5 per cent, silt loams 102.4, and sandy soils 105.7 per cent.

Results of cultivation experiments with corn carried on by the Illinois Experiment Station for 9 years have been reported by Mosier and Gustafson. The average yield of corn was 39.2 bushels on plots cultivated three times; 45.9 bushels where no cultivation was given but where weeds were kept down by scraping; and 7.3 bushels per acre on plots where the weeds were allowed to grow.

Mosier and Gustafson expressed the opinion that the injurious effects of weeds were due to other factors than depletion of moisture since parts of the weed plots were irrigated, and the yield was increased only 3 bushels over no irrigation. They thought that the removal of nutrients by the weeds was the important factor involved. Later in Illinois, Wimer and Harland (1925) added to the weed plot manure in proportion to the crop removed and also added 1 ton of rock phosphate and 2 tons of limestone per acre, and the yield was increased only 4.6 bushels over the unfertilized weed plot. It seems to the author that the removal of both moisture and nutrients by the weeds at critical periods is the serious factor; other factors may be involved such as reducing the CO_2 supply, shading the plants in the early stage of growth, and toxicity as mentioned in Chap. X.

In general, the experimental results justify the conclusion that the primary object of cultivation is the destruction of weeds and not the conservation of moisture by a dust mulch. There is some evidence that on heavy soils there is slight benefit from cultivation other than weed control. This benefit may be ascribed to better aeration due to the breaking up of the hard crust, but the evidence on this point is not conclusive.

Suckering.—The removal of suckers from the base of the plant is a very old practice and was formerly followed to a greater extent than it is today. In fact, it has been largely discontinued in field-corn culture and is not followed by many sweet-corn growers, although it is almost the universal practice in some localities as in Nassau County, N. Y. The advantages claimed for the practice are increased yield, larger size, and earlier maturity. Various writers have explained that removal of the suckers increases the yield because the raw materials brought into the plant from the soil would go to the ear instead of to the suckers. In this explanation the fact that the materials brought into the plant from the soil are not foods until they have undergone manufacture in the foliage is overlooked. The suckers themselves aid in this manufacture. These writers have tried to explain something that has not been proved and is probably not generally true.

Experiments conducted by the writer at Ithaca, N. Y., covering a period of 5 years and experiments by Thompson, Mills, and Wessels (1930) for 6 years on Long Island indicate that removal of the suckers tends to decrease the yield and does not appreciably hasten maturity or increase the size of the ears. The experiments at Ithaca were with Golden Bantam and Stowell's Evergreen. There were four treatments as follows:

(*A*) Not suckered (check).

(*B*) Suckers removed when the plants were 12 to 18 inches high.

(*C*) Suckers removed when the plants were 12 to 18 inches high and kept removed thereafter.

(*D*) Suckers removed when the plants began to tassel.

The treatments were by row, with the rows 150 feet long. Each treatment were replicated six times, or seven rows in each treatment. The rows were 3 feet apart, with the hills 2 feet apart in the row for Golden Bantam and 3 feet apart for Stowell's Evergreen. Each hill was thinned to three plants. The total yield, the yield at the first picking, the yield of grade 1, and the average size of ears are given in Table LXXIII. The figures given are averages for the 5 years.

A study of the data in Table LXXIII will show that the total yield of marketable ears was highest on the unsuckered rows, and that the late suckering decreased the yield markedly. The odds of significance computed by Students' Method indicate that the difference in total yields between treatments *A* and *B* and *A* and *C* was not significant, but that the difference between *A* and *D* of Stowell's Evergreen is significant, the odds being 399:1.

TABLE LXXIII.—EFFECT OF REMOVING SUCKERS ON YIELD, EARLINESS, GRADE, AND SIZE OF EARS
(Thompson, 1926)

Treatment	Total number ears	Yield, weight, in pounds	Yield first picking		Grade 1		Size of ears, ounces
			No.	Wt.	No.	Wt.	
			Golden Bantam				
A	1086	400.9	303	118.1	803	326.2	5.90
B	1042	387.9	324	127.7	783	313.6	5.95
C	1024	387.9	319	126.2	781	322.1	6.06
D	951	344.7	283	113.3	738	299.8	5.79
			Stowell's Evergreen				
A	692	508.1	290	227.4	498	412.2	11.74
B	672	488.9	303	237.2	482	394.9	11.63
C	676	499.1	327	252.8	492	402.1	11.81
D	650	476.1	289	228.4	470	382.0	11.71

In the case of the yield at the first picking, the difference between the unsuckered and suckered treatments is not significant with either variety. There is no significant difference between the suckered and unsuckered treatments as far as the yield of grade 1 ears is concerned.

In size of ears the difference between *A* and *C* of Golden Bantam is significant with odds of 49:1, but the other differences are not significant. In the case of treatment *C* of Golden Bantam, the ears averaged less than $\frac{1}{6}$ ounce more than the ears of treatment *A*; this is of no consequence.

In the experiments on Long Island, the Long Island Beauty variety was used in addition to the others, and the results were similar to those obtained at Ithaca, but with significant odds to show that late suckering reduced the total yield of marketable ears of all three varieties. Late suckering also reduced the yield of grade 1 ears. There was no significant difference in early yield or in size of ears between the treatments in these experiments.

In both sets of experiments, at Ithaca and on Long Island, the yield of stover was greatly reduced by removing the suckers. Late suckering of Long Island Beauty reduced the yield of stover approximately 3 tons to the acre. The stover is a valuable by-product used for livestock of various kinds.

Since the removal of suckers adds to the cost of production and, in the experiments mentioned, reduced the yield, when suckering was delayed, and since there were no appreciable and significant gains in earliness or in size of ears, it would seem that the practice is more likely to result in loss than in gain under most conditions. Jones and Rosa (1928) express the opinion that removing the suckers is desirable under California conditions, but they cite no experimental evidence. It seems entirely possible that under some conditions removing the suckers might pay, but the author believes that under average conditions in the eastern part of the United States it is more likely to result in loss than in gain.

Varieties.—Varieties of sweet corn are usually grouped into three classes: early, medium, and late. These terms are somewhat confusing since the so-called early varieties are often planted late in the season, much later than the so-called late varieties. The terms refer to the length of time required to produce edible ears, and when varieties of these three classes are planted at the same time in the spring "early," "medium," and "late" characterize them with reference to time of edible maturity. However, there is some overlapping.

Within recent years there has developed great interest in so-called hybrid sweet corn, several types of which are recognized. One kind results from a cross between two distinct varieties such as Stowell Evergreen and Golden Bantam which produced Bantam Evergreen. In this case, through continued breeding for several generations, the new variety Bantam Evergreen was developed and seed of this is produced by open pollination. Other types of hybrids are the result of first-generation crosses involving two or more inbred lines, or of a cross between a true variety and an inbred line. This latter kind of hybrid is known as top cross. The term hybrid as applied to corn commonly refers to the two latter types. Richey (1934) described the different kinds of hybrids as follows:

> Inbred strains may be combined into several different kinds of hybrids. Thus the single cross or hybrid is between 2 inbred strains, the three-way cross involves 3 strains, the double cross 4 strains, and the top cross involves 1 inbred strain and 1 open-pollinated variety. Each of these has certain advantages and disadvantages or fits into the corn-breeding program in a particular way.
>
> The simplest of these hybrids is the single cross, or hybrid between two strains. Thus, designating the female parent first in the customary way, B × A designated the single cross of strain B pollinated by strain A. The seed of the cross is that produced on the plants of strain B and usually will not appear noticeably different from self-pollinated seed of B. The vigor of hybridity

becomes evident, however, shortly after germination begins if the crossed seed is planted.

The three-way cross is the hybrid of a single cross between two inbred strains and a third inbred strain. It is customary to use the single cross as the female and the third inbred strain as the male parent in producing a three-way cross. Thus, (B × A) × C designated the single cross B × A pollinated by strain C. The crossed seed produced on the vigorous B × A plants is superior in quality and quantity to that produced on inbred plants as in single crosses.

Double crosses are hybrids between two single crosses, involving four different inbred strains. Thus, the double cross or hybrid (B × A) × (C × D) designates the hybrid of the single cross B × A pollinated by the single cross C × D. Here, both the male and female parent plants are vigorous hybrids. The seed quality and production are high, and there is every possible assurance of abundant pollen from the male parent, which is not true when this parent is an inbred strain.

The cross of a commercial variety and an inbred strain has been variously designated as a top cross, inbredsire cross, and the like. In limited experiments, some such crosses have yielded more than ordinary varieties but less than comparable double crosses.

The single cross is at a disadvantage because of low yield of seed and its consequent high cost. The seed is irregular in size and shape. While this makes uniform distribution in planting very difficult, it can be remedied to some extent by separating the sizes by use of sieves. Of all hybrids, single crosses produce the most uniform plants and ears and, for this reason, they have special value where uniformity is important, as in growing the crop for canning.

The three-way cross has no special advantage over the double cross, but Richey states that it is slightly more uniform. The disadvantage of the three-way cross is that an inbred line must be relied upon to supply the pollen for the cross. The three-way cross is impracticable unless an inbred line is available that is a good pollenizer. The double cross seems more practical than the three-way cross.

The advantage of the top cross over the others is that it is easier to find an inbred that will combine with some standard variety than to find three or four inbreds that will produce a good three-way or double cross. Top crosses provide an efficient means for preliminary testing of inbred strains for later use in hybrid combinations. Gemcross, Bancross, Marcross, and Whipcross represent top crosses.

Good hybrids average higher in yield and are more uniform in size, quality, and time of maturity than open-pollinated varieties. Not all hybrids are good, but usually the corn breeder discards the inferior ones. Haber (1934) reported tests of a number of single-cross hybrids which produced a large increase in yield over the best open-pollinated varieties. He also showed very large increases of variety-inbred crosses over the open-pollinated variety itself. The user of hybrid seed (seed resulting from cross pollination of two unrelated strains) should bear in mind that it is of value only in the first hybrid generation. Seed produced from this hybrid seed will yield less than the first generation and may be inferior to ordinary varieties.

Many of the old varieties such as Golden Bantam, Whipple Early, Whipple Yellow, Stowell Evergreen, Country Gentleman, and many others are still grown, but a considerable part of the present (1939) acreage of sweet corn is produced from hybrid seed. This seed is produced by specialists who maintain the inbreds, or obtain them from others, and procure the commercial crop of seed by growing rows of the two parents in an isolated field and detasseling the female parent. Richey states that from two to four rows of the female parent can be planted to every row of the male parent. The seed comes only from the female parent.

Many of the experiment stations conduct corn breeding work and maintain inbred lines for the production of hybrid seed. Some of the large seed companies and some individual growers also maintain inbred lines and produce hybrid seed from them. The sweet-corn grower should obtain his hybrid seed each year from dealers who are known to have seed that meet his needs. Since new hybrids come on the market each year there is little point to giving a list of the present ones. The reader should obtain this from the experiment station or other official source in his state.

Insects.—Several insects attack sweet corn and under some conditions do severe injury. The most destructive are the corn earworm, European corn borer, southern corn rootworm, cutworms, white grubs, and wireworms. The last three are discussed in Chap. XIII.

Corn Earworm.—This is a very serious pest of sweet corn in the South and in many sections of the North, but is usually not present in injurious numbers in the northern part of the sweet-corn belt. This insect is the same as the bollworm of cotton and the fruitworm of tomato. It is also called the tobacco budworm, and it attacks pumpkins, squashes, melons, peppers, and other vegetables. The worm is the larval stage of a moth (*Heliothis obsoleta*), which, when full grown, is 1½ to 2 inches long and varies in color from light green to brown. The eggs are laid on the silk and the larvae work their way down under the husk where they feed on the silk and unripe kernels. Even where the insects do not eat very much of the corn the injury is serious because of the entrance of rain through the opening made by the worm and this is followed by decay.

No satisfactory controls measures have been developed. Dusting the silks with insecticidal dusts has been tried without very efficient results. Recent experiments with some of the newer insecticides have given more encouraging results, but no recommendations can be made at this time. Clipping off the tip of the husk has been found of some value. This consists of removal of the silks and husk tips with sharp shears or grass clippers 3 or 4 days after most of the silks have appeared. Sometimes, a second clipping is made 4 or 5 days later. The removal of the silks get rid of most of the eggs, which are deposited there. This treatment has not been shown to be satisfactory in commercial plantings where the infestation is heavy.

Collins and Kempton (1917) obtained two dent varieties of corn that were highly resistant to earworm. These were crossed with three susceptible varieties of sweet corn and the hybrid progenies proved more resistant than the susceptible commercial varieties. Prolongation of the husk beyond the tips of the ear and thickness of the husks were found to be associated to some extent with small damage. Mangelsdorf in Texas developed two varieties, Honey June and Surecropper Sugar, by crossing two resistant dent varieties with Country Gentleman and by backcrossing to the dent parent for several generations. These two varieties have shown in tests in Texas and in California, according to Poole (1937), more resistance than any other varieties except Papago and Aunt Mary's Sweet. Other earworm resistant varieties are Florida 191 and Suwanee, developed by the Florida Experiment Station, and Georgia 439 and Georgia 428, developed by the Georgia Station. While these varieties may be useful in certain regions where the earworm is very serious, they have not replaced other varieties in the important sweet-corn producing states.

Crop rotation is of little value, as the insect feeds upon many kinds of plants, including grasses and clovers.

EUROPEAN CORN BORER (*Pyraŭsta nubilalis*).—This pest was recently introduced from Europe and is now found in New England, New York, Pennsylvania, Ohio, Indiana, Michigan, and Ontario. This is a serious pest to sweet corn since ears infested with the larvae are not desirable for market or for canning. Some canners in western New York discontinued canning corn on account of it. The larva is about $\frac{3}{4}$ inch long, yellowish gray in color with faint reddish or brownish stripes. The caterpillars bore into all parts of the plant except the root and cause great damage when they are present in considerable numbers. The breaking over of the tassels due to the feeding of the caterpillars, the sawdust-like borings on the stalks in midsummer, and later the breaking over of the stalk just above the ear are characteristics by which the presence of the insect may be detected.

This insect feeds upon a great many plants including vegetables and flowers, field corn, sorghums, millets, and a large number of weeds. This makes control very difficult if not impossible. To reduce the danger of serious damage and rapid spread to new territory, the following measures are recommended:

1. Cut the cornstalks early and as close to the ground as is practicable, and put the stalks in the silo, or feed them to livestock while they are still succulent.
2. Plow under the corn stubble and refuse deeply and cleanly in the fall of the year or early in the spring. All stalks and trash left in the field should be gathered and burned in the spring.
3. All weeds in the field and for 10 to 15 yards around the field should be plowed under or burned.

Transeau (1927), Sampson (1927), Sampson and Transeau (1928) have called attention to a correlation between the distribution of natural plant associations and infestations of the European corn borer. The borer seems to be most serious in regions originally occupied by the swamp formation—the series of successions from marsh grasses through intermediate bog and swamp vegetation to the elm-ash-maple swamp forest association. It is fairly well known that the borer does more serious damage in some sections than in others and this seems to be related to the ecological conditions.

For a full discussion of the status of the work on the corn borer, including studies in various fields, the reader is referred to *Bull.* 429 of the Ohio Agricultural Experiment Station.

Southern Corn Rootworm.—This pest is the larvae or young of the 12-spotted cucumber beetle. Great injury is often done to corn of all kinds and to many other food plants in the South, including peanuts, beans, and cucurbits. The injury to corn is done by the larvae in the spring when the plants are small. At this time they feed upon the roots and bud, boring through the crown at the base of the stalk to reach the bud. Injury is greatest when corn is planted in damp locations and in meadows.

When the insect is feeding upon the corn roots, insecticides are of no value, but destruction of the beetles when they feed upon the aboveground portions of cucurbits and other plants will reduce the injury done by the larvae. Crop rotation, using cotton, small grains, and vegetables other than beans and cucurbits will aid in controlling this insect.

Bacterial Wilt or Stewart's Disease.—This is caused by a bacterium *Phytomonas stewartii.* It is a very serious disease in many sweet-corn growing regions. It makes its appearance at any stage of growth, but is most noticeable when the plants attain considerable size. The plants are dwarfed; the tassel develops early, whitens, and soon dies; the leaves dry out; and the stem finally dies. A yellow slime may collect on the inner husks, and the stalk, if cut off near the base and squeezed, may show a yellow ooze at the ends of the strands. The bacterium can live through the winter in the seed and in the diseased stalks. It has been shown also that the parasite lives over winter within the adult flea beetles, which feed on corn plants early in the spring.

Recommended control measures include burning or placing in the silo the infected plants as soon as harvesting is completed; fall plowing; planting seed that is not infested; and delayed planting, if susceptible varieties must be planted. The best method of control is the use of resistant varieties, of which there are many. Most seed dealers now offer resistant strains of the various varieties, which should be obtained for regions where the bacterial wilt is serious.

Corn Smut (*Ustilago zeae*).—This disease occurs wherever corn is grown and is easily recognized in the later stages by the black masses upon the ear and tassel. The first symptom is a pale shining, swollen area covered with a white membrane, which soon appears black due to the maturing of the spores on the inside. The membrane finally bursts and releases a powdery, black mass of spores. The disease is not carried on the seed.

There is no practicable control except to gather and burn the smutted ears and stalks before the spores are released. This method is usually not practiced because the disease seldom affects more than 1 to 2 per cent of the ears.

Harvesting.—Sweet corn, to have high quality, should be harvested in the milk stage, since the sugar decreases and the starch increases as it passes from this stage to the dough stage. The water likewise decreases and the corn becomes harder. Analyses of Stowell's Evergreen reported by Appleman (1921) show the composition at various stages in the development of the kernels. While there was considerable difference in the composition of different samples representing any stage of ripening, the averages shown in Table LXXIV indicate quite well the changes

TABLE LXXIV.—AVERAGE PERCENTAGE COMPOSITION OF SWEET CORN AT DIFFERENT STAGES OF RIPENING

Crop	Stage of ripening	Number of tests	Moisture, per cent	Total sugar, per cent	Starch, per cent
Early	Premilk	9	85.10	6.26	3.29
Early	Milk	18	80.16	5.79	7.72
Early	Early dough	9	71.07	3.91	16.35
Early	Dough	18	63.92	3.17	21.62
Late	Premilk	14	88.75	5.76	2.71
Late	Milk	16	83.54	5.81	5.51
Late	Early dough	16	77.95	3.38	11.24

taking place during this period. Data were secured on two crops designated as "early" and "late."

An examination of Table LXXIV will show that as ripening proceeds the increase in the percentage of starch is greater than can be accounted for by the decrease in the percentage of sugar.

As mentioned in an earlier paragraph, the temperature at the time of ripening determines the rate of change from the milk to the dough stage. The higher the temperature, the faster the corn matures; for this reason close attention should be given to harvesting when the weather is hot.

After sweet corn is harvested, it should be handled quickly and at as low a temperature as possible for the quality deteriorates rapidly. There is a rapid loss of sugar at the temperatures that usually prevail during the corn-harvesting season, and only the home gardener can have sweet corn of the very best quality. Appleman and Arthur (1919) and Stevens and Higgins (1919) have shown that the rate of sugar loss increases with rise of temperature at least up to 30°C. Appleman and Arthur, working with Stowell's Evergreen, conducted a series of experiments in which sweet corn was kept at seven accurately controlled temperatures, namely 0°, 5°, 10°, 15°, 20°, 30° and 40°C. Analyses were made to determine the loss of sugar during consecutive 24-hour periods of storage at these temperatures and the results for five temperatures are shown in Table LXXV.

TABLE LXXV.—LOSS OF SUGAR FROM GREEN SWEET CORN DURING CONSECUTIVE 24-HOUR PERIODS OF STORAGE AT DIFFERENT TEMPERATURES. TOTAL SUGARS AND LOSSES ARE EXPRESSED IN PERCENTAGES

(Appleman and Arthur)

All Sugars

Number of hours in storage	Ear lot	Storage temperatures									
		0 degrees C.		10 degrees C.		20 degrees C.		30 degrees C.		40 degrees C.	
		Total[1]	Loss[1]	Total[1]	Loss[1]	Total[1]	Loss[1]	Total[1]	Loss[1]	Total[1]	Loss[1]
0	1*a*	5.91	....	5.83	....	6.17	....	5.34	....	6.72	
24	1*b*	5.43	0.48	4.83	1.00	4.59	1.58	2.65	2.69	3.64	3.08
24	2*a*	6.70	....	3.95	....	3.68	....	3.11	....	2.30	
48	2*b*	5.96	0.74	3.43	0.52	2.69	0.99	2.68	0.43	1.69	0.6
48	3*a*	6.63	....	4.61	....	3.07	....	2.10	....	2.00	
72	3*b*	6.36	0.27	3.92	0.69	2.52	0.55	2.03	0.07	1.90	0.10
72	4*a*	6.10	....	3.54	....	2.24	....	1.59			
96	4*b*	5.75	0.35	2.93	0.61	1.97	0.27	1.49	0.10		

[1] Total quantities of all sugars before and after storage and losses during storage are expressed in percentages.

Appleman and Arthur found that the depletion of sugar in green corn after it is separated from the stalk does not proceed at a uniform rate, but becomes slower until finally equilibrium is reached. This takes place when the total sugar has decreased about 62 per cent and the sucrose about 70 per cent. They showed that the rate of sugar loss increases as the temperature is raised, but that the raising simply hastens the attainment of the equilibrium, which seems to be about the same for all temperatures. The rate of sugar loss, until it reaches 50 per cent of the initial total sugar and 60 per cent of the sucrose, is doubled for every increase of 10° up to 30°C. This follows van'T Hoff's law for the rate of chemical reaction.

Sweet corn often becomes heated after being pulled from the stalk, especially when loaded into tight wagon beds for hauling to the canning factory. The load often stands overnight. Under such conditions the quality deteriorates rapidly, and while the sugar loss is made up by the addition of sugar when the corn is prepared for canning the product is not so good as when it is canned before it has changed in composition.

It is difficult for the inexperienced to determine when sweet corn is in the best edible condition without pulling down the husk and examining the kernels. The general appearance of the husk and silk and the plumpness of the ear are evidence of the stage of ripeness, and are sufficient for the average grower. By observing the general characters mentioned and correlating them with the stage of ripeness, as indicated by the nail test, the inexperienced will soon learn to determine when sweet corn should be harvested without examining the kernels. In the nail test the thumbnail is thrust into the kernel: if the exudate is milky, the corn is said to be in the milk stage; if dough is forced out of the kernel, the corn is said to be in the dough stage and is too ripe for the best quality.

The ears are usually pulled from the stalk by a quick jerk; if the shank at the base of the ear is too long, it is broken off. All ears should have about the same length of shank and the same amount of husk. The corn harvested for market is usually placed in boxes, baskets, or bags as removed from the stalk and placed on a wagon or truck. For the canning factory, the ears are sometimes thrown direct in to the wagon or truck.

Grading and Packing for Market.—Sweet corn is, as a rule, not very carefully graded, but the best growers do grade and find it a very desirable practice. Grading is especially important where the ears are put up in packages and of course, a package should contain only one grade. The best grade should contain ears of medium size and uniform in every particular.

Since market sweet corn is grown mainly by market gardeners the use of closed packages is not very common. All types of containers are used for conveying corn to local markets. Some markets use bushel boxes, others use baskets of various kinds, some use special crates. Bags are sometimes used but they are the least desirable type of container, since they do not show off the corn to good advantage and interfere with the circulation of air.

When sweet corn is to be shipped some distance the ears should be carefully packed in a well-ventilated crate or box and loaded into refrigerator cars. Even with the closest attention to these factors there is considerable deterioration in quality when the product is in transit 2 days or more.

Storage.—Sweet corn is not stored to any great extent; if cooled immediately after harvesting, it can be kept in fairly good condition for 3 or 4 weeks at 32°F. and at humidities of 90 to 98 per cent. Appleman and Arthur (1919) showed that the loss of sugar was about four times as rapid at 50°F. as at 32°F. At 32°F. more than 20 per cent of the initial sugar disappeared through respiration and conversion to starch in 4 days. Rate of sugar loss is much more rapid at the beginning than later.

OKRA

Okra or gumbo is an important crop in many parts of the Old World, where it is used in the dried form in large quantities. In the United States it is not of great commercial importance, although it is a popular vegetable in the South, where it is grown quite generally in the home garden.

History and Taxonomy.—Okra is thought to be of African or Asiatic origin, perhaps both. It was probably not cultivated during ancient times as it is not mentioned in early literature. It was known by the Spanish Moors and was used by the Egyptians in the twelfth or thirteenth century. Okra is mentioned as having been grown in Philadelphia in 1748 and was listed by Jefferson in 1781 as being grown in Virginia. McMahon (1806) also mentions its culture in the South.

Okra is known under the botanical name *Hibiscus esculentus* L., and belongs to the Malvaceae or mallow family. Many other species of hibiscus are used as foods in various parts of the world. In this genus belong many species of flowering hibiscus, several of which are native of the United States. Cotton is the most important economic plant belonging to the mallow family.

Culture.—Okra is a tender plant and grows best in hot weather. In regions having a short growing season and relatively cool nights, the crop does not thrive well. In such regions a supply for home use can be grown if quick-maturing, dwarf varieties are selected and the seed is planted as soon as the soil becomes warm.

One planting in the spring will supply a continuous harvest from the time the first pods develop until frost if the pods are kept picked and none allowed to ripen seed. Woodruff (1927) states that the maximum yield is produced in September in Georgia, but the harvest is continuous from the last of June until the plants are killed by frost.

Seed is drilled thickly in rows 2½ to 4 feet apart. When the plants are established they are thinned to stand 12 inches apart for dwarf varieties and 18 to 24 inches for the large varieties.

Any good garden soil will produce a satisfactory crop of okra if other conditions are favorable. If the soil is not rich, a liberal application of fertilizer or manure is desirable. A complete fertilizer high in nitrogen is recommended for the average sandy-loam soil where manure is not used. An application of 500 to 1,000 pounds to the acre of a 5–10–5 mixture is suggested.

The cultivation given okra should be about the same as for any other cultivated crop.

Varieties.—Beattie (1905) states that there are three general types of okra: tall green, dwarf green, and lady finger.

Each of these is again divided according to the length and color of the pods, making in all six classes, namely, tall green, long pod; tall green, short pod; dwarf green, long pod; dwarf green, short pod; lady finger, white pod; and lady finger, green pod. All variations from these are merely the results of mixtures, no true crosses or hybrids being formed. These mixtures are easily separated and referred to the parent type, and a little attention to rogueing and selection is necessary in order to keep the varieties pure. It is essential that the varietal strain should be pure in order that a uniform and marketable lot of pods may be produced.

Woodruff (1927) recommends the following varieties for Georgia: Dwarf Green, White Velvet, Perkins' Mammoth Long Pod, Dwarf, Dwarf White, and French Market. He reports yields per acre of 263.8 bushels of White Velvet, 315.3 bushels of Perkins' Mammoth Long Pod, and 336.4 bushels of Dwarf Green.

Harvesting.—The long seed pods are the edible portion, and as these develop rapidly, they should be gathered every day. Only the young tender pods are desired as the older pods become woody and tough. They are broken or cut from the stalk, and when they are to be marketed they should be sorted into the various sizes and packed in small baskets. The pods become tough quickly after being removed from the plant and, for this reason, should be placed on the market as soon as possible. Shipping to distant markets is not a common practice because the pods do not remain in good condition for a sufficient length of time.

Uses of Okra.—The principal use of okra is in soups and stews in which meats form an important part, as in the so-called gumbo soups. The pods are sometimes stewed and eaten as a vegetable, being seasoned with pepper, salt, and butter. Okra is sometimes canned, either alone or in a soup mixture with other vegetables. Okra or gumbo soup is very much relished by persons who have acquired a taste for it and it is a fairly common article of diet in the South.

In Turkey, the young pods of okra are dried in large quantities for use in the diet. Many tons of the dried product are brought into the United States each year in order to meet the demand among the foreign population, especially the Turks.

MARTYNIA

Martynia or Unicorn Plant (*Proboscidea Jussieui* Keller) is a native of southwestern United States. This plant has been known as *Martynia proboscidea*, *Martynia Louisiana*, and *Proboscidea Louisiana*, but according to Van Eseltine (1929), who has made a study of this group, the plant usually cultivated is P. *Jussieui*. It is grown to some extent in home gardens mainly as a curiosity, but its seed pods are used for pickling when young. The pods are green, very hairy, fleshy, 1½ inches at their greatest diameter tapering to a long, slender incurved beak or horn (Fig. 68). The plant grows 1½ to 2 feet high and is rather wide spreading.

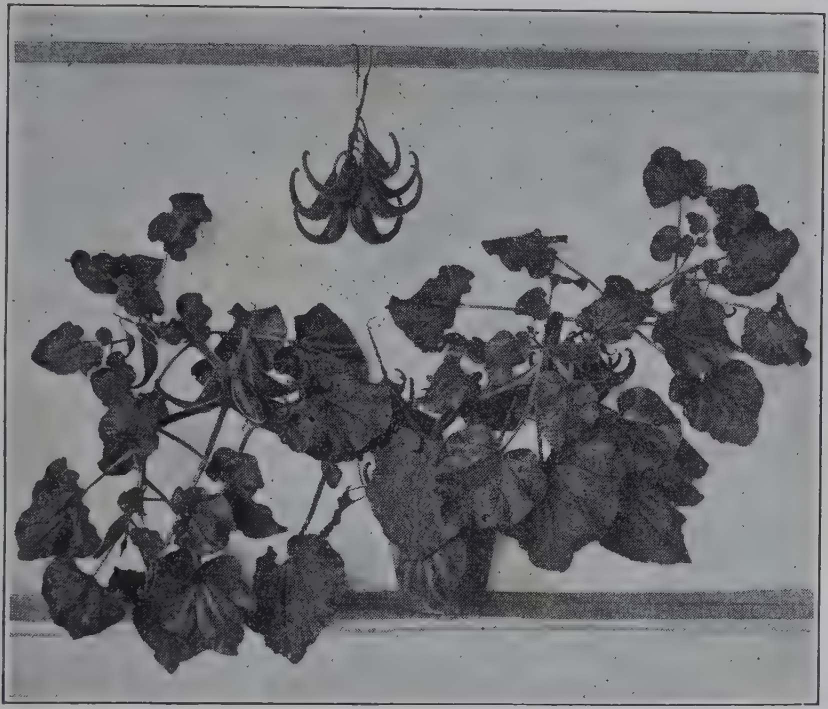

FIG. 68.—Martynia plant and fruit.

In the South, Martynia seed may be sown in rows 3 feet apart and the plants thinned to stand 18 to 24 inches apart in the row. In the North, the plants should be started in the greenhouse and later transplanted to the garden. A warm soil is especially desirable in the North. The general cultural requirements of this plant are about the same as for okra.

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